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Renewable Energy 32 (2007) 2223-2241

RENEWABLE ENERGY

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# Energy and exergy efficiencies of a hybrid photovoltaic-thermal (PV/T) air collector

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Received 22 January 2006; accepted 21 November 2006 Available online 1 February 2007

#### Abstract

In this communication, an attempt has been made to evaluate exergy analysis of a hybrid photovoltaic-thermal (PV/T) parallel plate air collector for cold climatic condition of India (Srinagar). The climatic data of Srinagar for the period of four years (1998–2001) has been obtained from Indian Metrological Department (IMD), Pune, India. Based on the data four climatic conditions have been defined. The performance of a hybrid PV/T parallel plate air collector has been studied for four climatic conditions and then exergy efficiencies have been carried out. It is observed that an instantaneous energy and exergy efficiency of PV/T air heater varies between 55–65 and 12–15%, respectively. These results are very close to the results predicted by Bosanac et al. [Photovoltaic/thermal solar collectors and their potential in Denmark. Final Report, EFP Project, 2003, 1713/00-0014, www.solenergi.dk/rapporter/pvtpotentialindenmark.pdf]. © 2006 Published by Elsevier Ltd.

Keywords: Exergy; Hybrid photovoltaic-thermal; Solar energy

# 1. Introduction

To evaluate the performance of a photovoltaic-thermal (PV/T) collector, the value of electricity versus the heat from the collector is important. The performance of a PV/T collector can be evaluated in terms of energy efficiency and exergy efficiency. Bosanac et al. defined energy efficiency as the total energy yield for a year [1]. The results are calculated from 1st law of thermodynamics and exergy efficiency as the total exergy yield per year,

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<sup>0960-1481/\$ -</sup> see front matter C 2006 Published by Elsevier Ltd. doi:10.1016/j.renene.2006.11.013

# Nomenclature

A	area of module (m <sup>2</sup> )
b	breadth (m)
$C_{\mathrm{a}}$	specific heat of air (kJ/kgK)
dx	elemental length (m)
EVA	ethyl vinyl acrelate
$h_{\mathrm{T}}$	heat transfer coefficient from back surface to air through tedlar $(W/m^2 K)$
$h_{\rm p1}$	penalty factor due to presence of solar cell material, tedlar and EVA
$h_{\rm p2}$	penalty factor due to presence of interface between tedlar and working fluid through absorber plate
I(t)	incident solar intensity (a function of time) on the inclined module surface $(W/m^2)$
$I_{\rm HB}$	terrestrial beam solar radiation on a horizontal surface at ground level $(W/m^2)$
$I_{\rm HD}$	diffuse solar radiation on horizontal surface at ground level $(W/m^2)$
$I_{\rm ON}$	normal extra terrestrial solar radiation $(W/m^2)$
$I_N$	normal terrestrial solar radiation at the ground level $(W/m^2)$
$K_1$	perturbation factor (dimensionless)
$K_2$	background diffuse radiation $(W/m^2)$
т	air mass (dimensionless)
$\dot{m}_a$	rate of flow of air mass (kg/s)
n	day of the year starting from January 1
L	length of the PV module (m)
PV	photovoltaic
PV/T	photovoltaic-thermal
$\dot{Q}_{ m u}$	monthly thermal energy $(W/m^2)$
$\dot{q}_{\mathrm{u}}$	rate of useful energy transfer $(W/m^2)$
$\dot{q}_{exergy}$	rate of exergy $(W/m^2)$
Т	number of sunshine hours (h)
$T_{\rm a}$	ambient temperature (°C)
$T_{\rm air}$	temperature of flowing air (°C)
$T_{airin}$	inlet air temperature (°C)
Tairout	outlet air temperature (°C)
$T_{\rm bs}$	back surface temperature of tedlar (°C)
$T_{\rm c}$	temperature of solar cell (°C)
$T_{\rm R}$	cloudiness/haziness factor (dimensionless)
$T_0$	reference ambient temperature (K)
$\Delta T$	difference between the ambient temperature and collector outlet temperature
$U_{\rm b}$	overall heat transfer coefficient from bottom to ambient $(W/m^2 K)$
$U_{\rm L}$	overall heat transfer coefficient from solar cell to ambient through top and
	back surface of insulation $(W/m^2K)$
$U_{ m t}$	overall heat transfer coefficient from solar cell to ambient through glass $(W_{1/2}^{\prime}W_{2})$
<b>T</b> 7	$cover (W/m^{2}K)$
$U_{\mathrm{T}}$	conductive heat transfer coefficient from solar cell to air through tedlar $(W/m^2 K)$

$U_{ m tT}$	overall heat transfer coefficient from glass to tedlar through solar cell $(W/m^2K)$
$U_{\rm tair}$	overall heat transfer coefficient from glass to ambient $(W/m^2 K)$
Greek L	etters
α	atmospheric transmittance
$\alpha_c$	absorptivity of solar cell
$\alpha_{\rm T}$	absorptivity of tedlar
$\beta_{\rm c}$	packing factor of solar cell
$\theta_{\mathbf{Z}}$	zenith angle (°)
$\eta_{c}$	efficiency of solar cell
$\eta_{\rm exergvov}$	overall exergy efficiency
$\eta_{o}$	electrical efficiency under standard test condition
$\eta_{\rm ov}$	overall thermal efficiency
τ	transmitivity of glass cover

which is the part of energy that could theoretically be converted to work in an initial Carnot process. The results are calculated from the 2nd law of thermodynamics known as the exergy efficiency. According to Coventry, exergy (sometimes called availability) is defined as the maximum theoretical useful work obtainable from a system as it returns to equilibrium with the environment [2].

Jones and Underwood have studied the temperature profile of a photovoltaic (PV) module in non-steady-state conditions [3]. They conducted experiments for cloudy as well clear day condition for energy analysis. The carrier of thermal energy associated with the PV module can either be air or water. The integrated arrangement for utilizing thermal energy as well as electrical energy, with a PV module is referred to as the hybrid PV/T system.

The hybrid PV/T system can be used for:

- (i) Air heating [4–12] and
- (ii) Water heating [6,13–19].

Performance of a PV/T system can be carried out either in terms of energy or exergy. Chow has analyzed the PV/T water collector with a single glazing in transient conditions, consisted of tubes, in thermal contact with the flat plate on account of metallic bond [16]. It has been observed that the electrical efficiency (the ratio of maximum power to the incident solar radiation) is increased by 2% at a mass flow rate of 0.01 kg/s due to decrease in temperature of solar cell of PV module and a plate to bond heat transfer coefficient  $10^4 \text{ W/m}^2 \text{ K}$  with an addition thermal energy efficiency of 60%. Huang et al. have experimentally analyzed unglazed integrated photovoltaic–thermal solar system (IPVTS) for water heating under natural mode of operation [20]. They observed that the primary energy-saving efficiency of the IPVTS exceeds 0.60, which is higher than that for a conventional solar water heater or pure PV system. Kalogirou has observed the monthly performance of a glazed hybrid PV/T system under forced mode of operation for the climatic condition of Cyprus [14]. He observed an

increase of the mean annual efficiency of the PV solar system from 2.8% to 7.7% with an associated thermal energy efficiency of 49%. A similar study has also been made by Zondag et al. [13]. They have referred to a hybrid PV/T as a combipanel, which converts solar energy into both electrical and thermal energy. The efficiency of the combi-panel was reported as 6.7% (electrical) and 33% (thermal energy), respectively.

Sandnes and Rekstad have studied the performance of a combined PV/T collector, which was constructed by pasting single crystal silicon cells onto a black plastic solar heat absorber (unglazed PV/T system) [18]. They recommended that the combined PV/T concept must be used for low-temperature thermal applications and for increasing the electrical efficiency of the PV system. Zakharchenko et al. have also studied unglazed hybrid PV/T systems with a suitable thermal contact between the panel and the collector [17]. To operate a PV module at low temperature, PV module should cover the low temperature part of the collector (e.g. at cold water inlet portion). Further, an unglazed hybrid PV/T system with a booster diffuse reflector was integrated with the horizontal roof of a building by Tripanagnostopoulos et al. [6]. They concluded that a PV/T system with a reflector yields distinctly clearly higher electrical and thermal energy output. They have studied the performance characteristic of a PV/T-water as well as a PV/T air system. An overall heat loss coefficient (U) and the thermal energy gain factor (q) for a combination of a ventilated vertical PV module and a double glazed window (PV facades) have derived by Infield et al. [5]. It is observed that the ventilated facades lead to enhancement of the electrical efficiency of a PV module on account of corresponding low temperature (generally below 45 °C). Hagazy and Sopian et al. investigated a glazed PV/T air system with a single or double pass air heater for space heating and drying [4,21]. They have developed thermal models for each system. The thermal energy, obtained from the glazed PV/T system gets increased along with lower electrical efficiency (due to high operating temperature). Further, Coventry has made an attempt to study the performance of a concentrating PV/T solar collector and concluded that overall thermal and electrical efficiencies of a PV/T concentrating system are 58% and 11%, respectively [22]. This gives a total energy efficiency of the system as 69%.

Little work has been carried out for exergy analysis of PV/T air/water heaters. Recently Bosanac et al. [1] have briefly carried out exergy analysis of PV/T system and reported that maximum exergy efficiency of PV/T system is about 12% against an overall maximum energy efficiency of 60%. Coventry and Lovehrove have also studied the exergy analysis of PV/T water system and reported that energy to exergy ratio of electrical and thermal are 1 and 16.8, respectively [2].

In this paper, an attempt has been made to study the exergy efficiency of unglazed PV/T air heating module for the cold and cloudy condition of Srinagar.

# 1.1. Hybrid PV/T air collector

Fig. 1a shows the schematic diagram of a PV/T air collector. Air has been considered as the medium for transport of thermal energy. Two PV modules with an effective area of  $0.61 \text{ m}^2$  each are connected in series. The module has been mounted on a wooden structure with the air duct below the module known as tedlar. In other words tedlar is an insulating and non-corrosive material used beneath the solar cell for better support to PV module.



Fig. 1. (a) Schematic diagram of integrated PV/T system (IPVTS) when air is used as the medium to collect thermal energy. (b) Cross-sectional view (rotated at  $90^{\circ}$  from horizontal) of hybrid PV/T air collector with temperature profile. (c) An elemental length 'dx' shows flow pattern of air below tedlar.

Table 1

Parameters	Values	Parameters	Values
A	0.61 m <sup>2</sup>	$U_{\mathrm{b}}$	$0.62  W/m^2  K$
В	0.45 m	$U_{\mathrm{t}}$	$2.8  \text{W/m}^2  \text{K}$
$h_{p1}$	0.88	$U_{ m tT}$	$8.11  \text{W/m}^2  \text{K}$
L	1.2 m	$U_{\mathrm{T}}$	$66  W/m^2  K$
$\beta_{\rm c}$	0.83	α <sub>c</sub>	0.90
$\eta_{\rm c}$	0.12	αΤ	0.50
τ	0.95	$h_{ m T}$	$6.5  W/m^2  K$

Design parameters for integrated photovoltaic thermal system with air as the heat removal medium [12]

There is a provision for inlet and outlet air to flow through the duct. The PV module with a wooden structure is placed on a steel frame.

The design parameters of hybrid PV/T system are given in Table 1.

# 2. Methodology

## 2.1. Evaluation of solar radiation

The data of global radiation and diffuse radiation are obtained from Indian Metrological Department (IMD) Pune, India for the years 1991–2001. Singh and Tiwari has defined the day of the year for four different weather conditions in terms of number of sunshine hours and ratio of daily diffuse to daily global radiation as described below [23]:

(a) Clear day (blue sky):	The ratio of daily diffuse to daily global radiation less then or equal to 0.25 and number of sunshine hours greater then or equal to 9 h.
(b) Hazy day (fully):	The ratio of daily diffuse to daily global radiation between 0.25 and 0.50 and number of sunshine hours between 7 and 9 h.
<ul><li>(c) Hazy and cloudy</li><li>(partially):</li><li>(d) Cloudy day (fully):</li></ul>	The ratio of daily diffuse to daily global radiation between $0.5$ and $0.75$ and number of sunshine hours between 5 and 7 h. The ratio of daily diffuse to daily global radiation greater then or equal to $0.75$ and number of sunshine hours less then or equal to 5 h.

The average values of global and diffuse radiation on horizontal surface for each case and month are given in Tables 2 and it has been used to evaluate cloudiness/haziness and atmospheric transmittances [23]. The results are given in Table 3 for all the four type of days.

The values of Table 3 has been used to calculate beam and diffuse radiation on horizontal surface for each case and month by using the following equation [23]:

$$I_{\rm HB} = I_{\rm ON} \exp[-(m\varepsilon T_{\rm R} + \alpha)] \cos(\theta_Z) = I_{\rm N} \cos(\theta_Z), \tag{1}$$

where  $I_{HB}$  is terrestrial beam solar radiation at ground level in W/m<sup>2</sup>,  $I_{ON}$  is normal extra terrestrial beam solar radiation in W/m<sup>2</sup>, *m*, air mass (dimensionless) is the ratio of optical

Table 2

Average hourly global (Ig) and diffuse (Id) radiation (W/m<sup>2</sup>) for the months of January–December (IMD)

Jan         Feb         Mar         Apr         May         June         July         Aug         Sep         Oct         Nov         Dec           Type a         Global         Sam         73.61         69.79         221.53         373.06         408.52         434.92         408.89         289.58         291.25         179.42         66.67         30.55           10am         455.55         481.60         667.74         756.37         395.25         796.43         788.06         711.11         668.47         744.75         452.78         384.34         457.19         452.78         543.22         177.78         732.99         891.43         925.20         981.61         951.19         950.28         858.42         842.71         719.34         652.78         563.89         40.77         700.66         622.53         563.89         40.73           3pm         418.06         652.50         703.71         73.66         783.15         61.71         128.48         75.76         83.32         90.61.71         47.84         42.16.67         20.78           piffuse         8am         19.45         45.48         74.31         90.03         12.65         13.34         14.12.14         14.72	Radiation	Time	Month											
Type a         Sam         73.61         69.79         221.53         373.06         408.52         434.92         408.89         289.58         291.25         179.42         66.67         30.55           9am         252.78         284.72         461.57         594.31         633.52         634.52         626.11         542.71         492.78         379.32         272.22         213.89           11am         545.84         647.22         800.70         880.56         915.19         950.28         885.42         84.271         719.34         652.87         533.89         795.24         702.8         854.29         82.77         702.06         622.53         563.89         470.37           3pm         418.06         562.50         703.71         735.66         763.89         795.24         717.8         83.75         700.66         622.53         503.88         471.746         317.78         83.36         61.11         84.80         80.56         62.61         550.55         53.38         400.49         290.84         216.67         218.85           5ym         43.06         177.08         24.34         145.56         117.76         177.78         133.68         147.15         131.38         16.11 <th></th> <th></th> <th>Jan</th> <th>Feb</th> <th>Mar</th> <th>Apr</th> <th>May</th> <th>June</th> <th>July</th> <th>Aug</th> <th>Sep</th> <th>Oct</th> <th>Nov</th> <th>Dec</th>			Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Global         8am         73.61         69.79         221.53         373.06         608.52         634.52         528.58         291.25         179.42         66.67         30.55           9am         252.78         284.72         66.57         976.53         793.52         796.43         788.06         711.11         668.47         542.74         422.78         379.32         272.22         213.89         501.91         502.88         854.24         62.71         71.93.4         552.78         543.57         600.66         622.23         51.83         598.99         47.83         25.77         82.69         47.78         73.69         62.24         71.79         74.59         961.71         904.86         55.84.37         70.60         622.23         53.89         47.06         612.71         479.84         80.56         362.04           410m         22.77.8         366.60         498.15         531.11         505.55         54.34         40.049         20.84         16.63         33.33         2.78           9am         70.83         11.46         105.22         122.79         151.11         128.82         121.87         95.68         18.34         143.58         153.33         61.11         121.83	Type a													
9am 25.278 284.72 461.57 594.31 633.52 634.52 626.11 542.71 492.78 379.2 272.22 213.89 10am 455.56 44106 665.74 776.53 793.52 796.43 788.06 711.11 688.47 544.75 452.78 360.19 12pm 577.78 732.99 891.43 932.50 981.67 951.19 950.28 885.42 842.71 719.4 652.78 543.52 1pm 572.22 74.75 905.79 931.81 975.74 904.76 888.89 934.7 83.25 770.20 6 622.2 513.89 2pm 511.11 688.20 841.67 870.70 913.70 919.84 850.55 843.75 760.69 622.71 479.84 850.65 62.04 4pm 227.78 356.60 498.15 531.11 560.56 626.19 550.55 534.38 400.49 290.84 216.67 201.85 5pm 43.06 127.08 245.37 283.06 344.81 417.46 317.78 293.40 196.11 94.86 25.00 52.78 Diffuse 8am 19.45 45.48 74.31 99.03 104.26 102.78 119.72 106.60 89.13 61.663 33.33 29.63 10am 101.39 112.50 122.38 138.47 143.56 135.29 164.17 125.35 138.47 113.89 158.33 61.11 11am 115.28 12.78 143.52 152.08 152.59 130.56 176.39 133.68 147.15 131.28 152.83 130.4 11pm 119.44 136.46 153.70 156.25 151.30 135.32 166.94 127.08 149.68 137.14 136.11 94.44 1pm 118.06 134.72 144.91 150.97 147.22 132.14 152.78 127.08 142.29 122.21 127.8 112.66 2pm 118.06 134.72 144.91 150.97 147.22 132.14 152.78 17.08 142.29 125.21 127.78 112.56 2pm 18.06 144.79 62.04 95.00 109.48 84.94 100.26 77.13 610.42 77.18 155.53 3pm 84.72 95.14 120.37 142.50 134.44 121.03 140.56 107.64 108.54 84.67 58.33 95.37 4pm 48.61 77.08 90.74 130.83 134.45 111.51 130.28 100.00 26.13 22.22 03.7 8m 25.70 86.11 146.43 266.88 359.83 366.03 316.58 267.13 250.82 168.98 46.20 33.33 5pm 18.06 447.9 62.04 95.00 194.84.84 101.25 107.64 108.54 84.67 58.33 95.37 4pm 418.61 131.91 32.64 446.75 637.65 672.49 555.69 538.89 463.40 364.82 184.35 202.78 10am 315.05 474.31 556.75 676.28 733.98 755.88 713.58 671.29 636.77 525.00 339.72 277.78 11am 421.53 719.44 661.51 826.92 857.91 919.23 892.03 864.82 742.16 639.58 462.50 341.67 12pm 43.68 81.45 135.72 446.37 553.88 88.09 890.87 71.34 636.77 525.00 339.72 277.78 11am 421.53 719.44 661.51 826.92 857.91 91.23 892.03 845.82 70.22 44.84 33.80 255.88 02.77 75 12pm 43.68 81.44 33 50.63 31.94 810.71 73 303	Global	8am	73.61	69.79	221.53	373.06	408.52	434.92	408.89	289.58	291.25	179.42	66.67	30.55
10am         45.55         481.60         665.74         776.53         793.52         796.43         788.06         711.11         668.47         544.73         661.83         558.33         485.19           12pm         577.78         732.99         891.43         932.50         981.67         951.19         950.28         885.42         842.71         719.34         652.78         543.52           1pm         577.22         747.57         905.79         91.84         805.58         91.57         91.84         805.58         843.57         700.66         622.53         563.84         90.64         90.68         30.63         21.71         79.84         80.05         51.51         51.51         51.51         60.66         62.19         50.55         534.38         400.49         209.84         21.66         20.18         52.00         52.78           9am         70.83         11.46         163.22         122.99         151.11         560.56         62.19         50.55         534.38         40.49         20.94         21.08         33.33         2.78           9am         70.83         11.46         163.21         122.99         121.11         128.53         13.44         143.50		9am	252.78	284.72	461.57	594.31	633.52	634.52	626.11	542.71	492.78	379.32	272.22	213.89
11am 545.84       647.22       800.70       880.59       915.74       904.76       888.89       831.60       784.30       661.83       558.33       485.19         1pm       572.22       747.57       905.79       931.81       975.74       963.89       958.89       903.47       832.57       702.06       622.23       563.89       470.37         3pm       418.06       562.50       703.71       735.69       783.89       795.24       72.78       745.49       480.65       840.55       840.71       479.84       800.56       362.01       480.55       840.71       479.84       800.56       362.11       480.55       840.71       479.84       800.56       362.11       470.57       278.06       480.55       840.71       470.85       578.83       400.49       200.44       166.33       33.33       2.78       93m       708.33       111.46       105.21       122.92       129.63       125.79       131.41       13.89       158.33       1.11       111       111       111       111       111.80       11.81       112.61       122.85       13.84       147.15       13.28       18.43       11.1       13.41       13.61       13.44       121.61       12.12       127.78 </td <td></td> <td>10am</td> <td>455.56</td> <td>481.60</td> <td>665.74</td> <td>776.53</td> <td>793.52</td> <td>796.43</td> <td>788.06</td> <td>711.11</td> <td>668.47</td> <td>544.75</td> <td>452.78</td> <td>360.19</td>		10am	455.56	481.60	665.74	776.53	793.52	796.43	788.06	711.11	668.47	544.75	452.78	360.19
12pm 577,27       732.99       891.43       932.50       981.67       951.19       950.28       885.42       842.71       702.06       622.22       513.89         2pm 511.11       688.20       841.67       870.70       913.89       757.47       963.89       955.88       903.47       975.79       623.95       863.89       402.77       873.69       783.89       795.24       727.78       745.49       612.71       497.84       380.56       484.81       51.55       533.43       400.49       209.44       216.67       201.85       533.43       400.49       209.44       216.67       201.85       533.43       400.49       209.44       216.67       201.85       533.43       400.49       209.44       216.67       201.85       533.43       400.49       209.44       216.67       201.85       533.61       111       400.61       143.23       126.61       103.33       216.67       201.85       320.63       103.41       104.71       125.51       138.47       113.89       135.35       111       128.82       128.82       128.83       111.41       131.41       130.11       44.44       110.91       118.06       113.41       130.51       147.42       133.45       111.52       123.44		11am	545.84	647.22	800.70	880.56	915.74	904.76	888.89	831.60	784.30	661.83	558.33	485.19
Ipm         572.22         747.57         905.79         931.81         975.74         963.89         988.89         903.47         832.57         700.06         622.32         563.89         470.37           3pm         418.06         562.50         703.71         735.69         783.89         795.24         727.78         745.49         612.71         479.84         880.56         362.04           4pm         227.78         356.60         498.15         531.11         500.56         62.619         550.55         534.38         400.49         20.84         216.67         201.85           5pm         43.06         127.08         245.37         283.06         344.81         417.46         317.78         293.40         196.11         94.82         20.08         21.67         151.11         128.82         121.87         95.68         108.33         29.63           10am         101.39         112.60         123.38         138.47         145.56         139.29         164.17         113.48         158.33         61.11           11am         115.26         112.76         143.25         112.06         137.41         121.31         122.21         127.78         105.55         39m         148.06 <td></td> <td>12pm</td> <td>577.78</td> <td>732.99</td> <td>891.43</td> <td>932.50</td> <td>981.67</td> <td>951.19</td> <td>950.28</td> <td>885.42</td> <td>842.71</td> <td>719.34</td> <td>652.78</td> <td>543.52</td>		12pm	577.78	732.99	891.43	932.50	981.67	951.19	950.28	885.42	842.71	719.34	652.78	543.52
2pm         511.11         688.20         841.67         7760.69         622.53         563.89         470.37           3pm         418.06         562.50         703.71         735.69         783.89         795.24         727.8         735.69         783.89         795.24         727.8         735.69         783.89         795.24         727.8         735.69         783.89         795.24         727.78         735.69         783.89         795.24         778.7         745.49         196.11         94.86         25.00         52.78           Diffuse         8am         19.45         45.48         74.31         99.03         104.26         102.78         119.72         106.60         89.31         61.63         33.33         2.78           98.70         111.46         105.23         153.10         156.25         153.10         156.41         171.11         132.81         147.12         132.44         123.13         147.12         132.41         152.76         137.69         149.86         137.14         136.11         94.44         110.31         130.28         140.56         176.44         183.44         120.31         142.50         134.44         120.31         142.50         134.44         120.31 <t< td=""><td></td><td>1pm</td><td>572.22</td><td>747.57</td><td>905.79</td><td>931.81</td><td>975.74</td><td>963.89</td><td>958.89</td><td>903.47</td><td>832.57</td><td>702.06</td><td>622.22</td><td>513.89</td></t<>		1pm	572.22	747.57	905.79	931.81	975.74	963.89	958.89	903.47	832.57	702.06	622.22	513.89
3pm         418.06         562.50         703.71         735.569         783.89         795.24         727.78         745.49         612.11         429.86         201.85         550m         43.06         127.08         245.37         283.06         344.81         417.46         317.78         293.40         196.11         94.86         25.00         52.78           Diffuse         8am         19.45         45.48         74.31         99.03         104.26         102.78         112.50         123.38         138.47         145.56         139.29         164.17         125.35         138.47         113.89         152.29         129.61         167.39         133.68         147.15         131.28         172.22         81.81           11m         115.24         127.78         143.52         152.09         133.44         127.08         149.48         137.14         136.11         144.44         120.78         142.29         125.21         127.21         126.21         127.21         126.21         127.21         126.21         127.21         126.21         127.21         126.21         127.28         132.44         120.37         142.29         125.77         147.98         148.33         102.33         129.33         129.37		2pm	511.11	688.20	841.67	870.70	913.70	919.84	850.55	843.75	760.69	622.53	563.89	470.37
4pm         227.78         336.60         498.15         531.11         500.56         524.38         400.9         20.84         216.67         201.85           biffuse         8am         19.45         45.48         74.31         99.03         104.26         102.78         119.72         106.60         89.31         61.63         33.33         2.78           9mm         70.83         111.46         105.32         122.92         129.63         125.79         130.66         147.17         125.35         138.47         113.89         158.33         61.11           11am         115.28         127.78         143.64         157.01         150.51         151.11         128.82         128.79         136.68         147.17         131.28         172.22         25.14           11am         115.28         127.78         142.50         157.01         153.25         166.94         127.08         142.29         122.14         127.78         142.50         127.78         142.50         127.78         104.29         127.78         104.29         127.78         157.78         104.54         16.76         108.3         33.33         95.37           118.06         113.09         126.4         130.78		3pm	418.06	562.50	703.71	735.69	783.89	795.24	727.78	745.49	612.71	479.84	380.56	362.04
5pm         43.06         127.08         245.37         283.06         344.81         417.46         317.78         293.40         196.11         94.86         25.00         52.78           Diffuse         8am         19.45         45.48         74.31         90.03         104.26         102.78         119.72         106.08         83.33         2.78           101.39         112.50         123.38         138.47         145.56         139.29         151.11         128.82         121.87         95.68         108.33         20.63           111         113.01         152.51         130.45         155.23         164.71         123.52         164.71         123.52         127.08         142.29         122.21         127.18         143.89         133.33         61.11         94.44           118.06         134.72         95.14         120.37         147.44         121.03         140.56         107.64         108.54         84.67         58.33         95.37           48.06         44.79         62.04         95.00         109.45         88.49         100.28         78.13         60.00         26.13         22.22         20.37           Bibbo         9am         165.51         250.00		4pm	227.78	356.60	498.15	531.11	560.56	626.19	550.55	534.38	400.49	290.84	216.67	201.85
Diffuse         8am         19.45         45.48         74.31         99.03         104.26         102.78         119.72         106.60         89.31         61.63         33.33         2.78           9am         70.83         111.46         105.32         122.92         129.63         125.35         138.47         113.89         158.33         61.11           11am         115.20         127.78         143.52         152.08         152.59         130.56         176.39         133.68         147.15         131.28         158.35         61.11           11am         115.20         134.72         144.91         150.97         147.12         132.14         152.78         127.08         142.20         122.12         127.78         112.96           2pm         184.06         113.19         132.64         143.75         147.41         121.43         144.72         10.67         127.36         104.42         77.78         80.33           5pm         84.61         70.80         0.74         130.83         134.45         111.51         130.28         10.60         61.3         2.22         20.37           8am         25.70         86.11         164.63         26.68         359.83		5pm	43.06	127.08	245.37	283.06	344.81	417.46	317.78	293.40	196.11	94.86	25.00	52.78
9am         70.83         111.46         105.32         122.92         129.63         125.79         151.11         128.82         121.87         95.68         108.33         29.63           10am         101.39         112.50         123.38         184.32         152.08         152.59         130.56         176.39         138.64         147.15         131.28         172.22         28.18           12pm         119.44         134.64         153.70         156.25         151.30         135.52         166.94         127.08         142.29         122.11         127.78         112.96           2pm         118.06         113.19         132.64         143.75         147.41         121.43         144.72         122.08         106.57         106.67         108.54         84.67         58.33         95.37           420m         48.61         77.08         90.74         130.83         134.45         111.15         130.28         100.69         100.00         84.44         33.33         83.33         50.00         84.72         95.14         146.43         266.88         59.13         60.00         66.13         22.22         20.37           8am         25.00         369.05         547.76         <	Diffuse	8am	19.45	45.48	74.31	99.03	104.26	102.78	119.72	106.60	89.31	61.63	33.33	2.78
10am         101.39         112.50         123.38         138.47         145.56         139.29         164.17         125.37         133.68         147.15         131.28         172.22         85.18           12pm         119.44         136.46         152.59         130.52         165.39         127.08         142.29         125.21         127.78         112.96           2pm         118.06         134.72         144.91         150.97         147.22         132.14         152.78         127.08         142.29         125.21         127.78         105.55           3pm         18.06         141.79         62.04         95.00         134.44         121.03         140.56         107.64         108.54         84.67         83.33         83.33           5pm         18.06         44.79         62.04         95.00         109.45         88.49         100.28         78.13         60.00         26.13         22.22         20.37           8am         25.70         86.11         146.43         266.88         359.83         16.53         250.02         168.98         463.40         364.82         184.35         202.78           10am         155.5         76.28         73.98         755.89		9am	70.83	111.46	105.32	122.92	129.63	125.79	151.11	128.82	121.87	95.68	108.33	29.63
11am       115.28       127.78       143.52       152.08       152.09       130.56       176.39       133.68       147.15       131.28       172.22       85.18         12pm       119.44       136.64       153.70       156.25       151.30       135.21       166.94       127.08       142.29       125.21       127.78       112.92         pm       118.06       13.19       132.64       143.75       147.41       121.43       144.72       116.67       127.36       104.42       77.78       105.55         3pm       84.72       95.14       120.37       142.50       134.44       121.03       140.56       107.64       108.54       84.67       78.33       85.37         48.06       77.08       90.74       130.83       134.45       111.51       130.28       100.69       90.00       58.44       33.33       83.33         sam       25.70       86.11       146.43       266.88       359.83       366.03       316.58       761.32       500.00       369.05       464.96       547.76       572.49       555.69       538.89       463.40       364.82       184.35       202.78         11am       415.53       719.44       661.28 <t< td=""><td></td><td>10am</td><td>101.39</td><td>112.50</td><td>123.38</td><td>138.47</td><td>145.56</td><td>139.29</td><td>164.17</td><td>125.35</td><td>138.47</td><td>113.89</td><td>158.33</td><td>61.11</td></t<>		10am	101.39	112.50	123.38	138.47	145.56	139.29	164.17	125.35	138.47	113.89	158.33	61.11
12pm       119.44       136.46       153.70       156.25       151.30       135.32       166.94       127.08       142.29       125.21       127.78       112.96         2pm       118.06       134.72       142.50       132.44       152.78       121.43       144.72       122.91       125.21       127.78       112.96         2pm       118.06       13.19       132.64       143.75       147.41       121.43       144.72       116.77       122.36       104.42       77.78       112.96         3pm       84.72       95.14       120.37       142.50       134.44       11.31       130.28       100.69       90.00       88.44       33.33       95.37         4pm       48.61       77.08       90.74       130.83       134.45       111.51       130.28       100.00       26.13       22.22       20.37       88       82.70       86.11       146.43       266.88       39.83       366.03       316.58       267.13       250.80       364.82       78.42       78.13       663.67       752.49       555.69       53.89       463.40       34.82       184.35       202.78       11.41       143.16.7       11.29       464.41.67       12.50       77.8 <td< td=""><td></td><td>11am</td><td>115.28</td><td>127.78</td><td>143.52</td><td>152.08</td><td>152.59</td><td>130.56</td><td>176.39</td><td>133.68</td><td>147.15</td><td>131.28</td><td>172.22</td><td>85.18</td></td<>		11am	115.28	127.78	143.52	152.08	152.59	130.56	176.39	133.68	147.15	131.28	172.22	85.18
Ipm       118.06       13.72       144.91       150.97       147.22       132.14       152.78       127.08       142.29       125.21       127.78       112.96         2pm       118.06       113.19       132.64       143.75       147.41       121.03       144.72       116.67       127.36       104.42       77.78       105.55         3pm       48.72       95.14       120.37       142.50       134.44       111.51       130.28       100.69       90.00       58.44       33.33       83.33         5pm       18.06       44.79       62.04       95.00       109.45       88.49       100.28       78.13       60.00       26.13       22.22       20.37         8am       25.70       86.11       146.43       266.88       359.83       366.03       316.58       267.13       250.02       38.92       277.78       112.96         Global       9am       165.51       250.00       369.05       464.96       547.76       572.49       555.69       538.89       463.40       364.82       184.35       202.78         10am       315.05       474.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77		12pm	119.44	136.46	153.70	156.25	151.30	135.32	166.94	127.08	149.86	137.14	136.11	94.44
2pm       118.06       113.19       132.64       143.75       147.41       121.43       144.72       116.67       127.36       104.42       77.78       105.55         3pm       84.72       95.14       120.37       142.50       134.44       121.03       140.56       107.64       108.54       84.67       58.33       95.37         4pm       48.61       77.08       90.74       130.83       134.45       111.51       130.28       100.69       90.00       58.44       33.33       83.33         5pm       18.06       44.79       62.04       95.00       109.45       88.49       100.28       78.13       60.00       26.13       22.22       20.37         8am       25.70       86.11       146.32       266.88       359.83       366.03       316.58       267.13       250.00       364.82       184.35       202.78         10am       315.05       74.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77       525.00       339.72       277.78         11am       421.53       719.44       661.51       826.92       857.91       91.23       892.03       861.25       761.44       677.78		1pm	118.06	134.72	144.91	150.97	147.22	132.14	152.78	127.08	142.29	125.21	127.78	112.96
3pm       84.72       95.14       120.37       142.50       134.44       121.03       140.56       107.64       108.54       84.67       58.33       95.37         4pm       48.61       77.08       90.74       130.83       134.45       111.51       130.28       100.69       90.00       58.44       33.33       83.33         5pm       18.06       44.79       62.04       95.00       109.45       88.49       100.28       78.13       60.00       26.13       22.22       20.37         8am       25.70       86.11       146.43       266.88       359.83       366.03       316.58       267.13       250.82       168.98       463.40       364.82       184.35       202.78         10am       315.05       474.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77       52.00       339.72       277.78         11am       421.53       719.44       661.51       826.92       875.91       919.23       892.03       864.82       742.16       639.58       462.50       341.67         12pm       463.66       81.25       750.00       65.87       673.29       711.65       808.60       769.77 <td rowspan="2"></td> <td>2pm</td> <td>118.06</td> <td>113.19</td> <td>132.64</td> <td>143.75</td> <td>147.41</td> <td>121.43</td> <td>144.72</td> <td>116.67</td> <td>127.36</td> <td>104.42</td> <td>77.78</td> <td>105.55</td>		2pm	118.06	113.19	132.64	143.75	147.41	121.43	144.72	116.67	127.36	104.42	77.78	105.55
4pm       48.61       77.08       90.74       130.83       134.45       111.51       130.28       100.69       90.00       58.44       33.33       83.33         5pm       18.06       44.79       62.04       95.00       109.45       88.49       100.28       78.13       60.00       26.13       22.22       20.37         8am       25.70       86.11       146.43       266.88       359.83       366.03       316.58       267.13       250.82       168.98       46.20       33.33         Type b       9am       165.51       250.00       369.05       464.96       547.76       572.49       555.69       538.89       463.40       364.82       184.35       202.78         10am       315.05       474.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77       525.00       339.72       277.78         11am       421.53       719.44       661.51       826.92       857.91       919.23       892.03       864.82       742.16       639.06       518.52       250.00         1pm       473.18       816.67       811.32       880.66       888.49       448.48       800.82       761.44       677.7		3pm	84.72	95.14	120.37	142.50	134.44	121.03	140.56	107.64	108.54	84.67	58.33	95.37
Spm       18.06       44.79       62.04       95.00       109.45       88.49       100.28       78.13       60.00       26.13       22.22       20.37         Sam       25.70       86.11       146.43       266.88       359.83       366.03       316.58       267.13       250.82       168.98       46.20       33.33         Type b       Global       9am       165.51       250.00       369.05       464.96       547.76       572.49       555.69       538.89       463.00       364.82       184.35       202.78         Iam       315.05       747.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77       525.00       339.72       277.78         Iam       421.53       719.44       661.51       826.92       857.91       919.23       888.80       89.08       761.93       693.06       18.52       525.00       341.67         12pm       463.66       81.32       880.60       769.77       730.93       694.77       593.29       473.89       491.67         3pm       361.81       585.41       355.72       446.37       355.13       542.84       590.17       637.50       527.29       44		4pm	48.61	77.08	90.74	130.83	134.45	111.51	130.28	100.69	90.00	58.44	33.33	83.33
8am         25.70         86.11         146.43         266.88         359.83         366.03         316.58         267.13         250.82         168.98         46.20         33.33           Type b           Global         9am         165.51         250.00         369.05         464.96         547.76         572.49         555.69         538.89         463.40         364.82         184.35         202.78           10am         315.05         474.31         556.75         676.28         733.98         755.88         713.58         671.29         63.67         520.00         39.02         277.78           11am         421.53         719.44         661.51         826.92         857.91         919.23         892.03         664.82         742.16         639.58         462.50         341.67           12pm         463.66         813.25         769.05         858.55         893.16         878.53         888.80         890.08         761.94         677.78         521.20         544.44           pm         361.81         585.41         355.72         446.37         355.13         542.84         590.17         637.50         527.29         448.61         357.59         217.78		5pm	18.06	44.79	62.04	95.00	109.45	88.49	100.28	78.13	60.00	26.13	22.22	20.37
Type b       Global       9am       165.51       250.00       369.05       464.96       547.76       572.49       555.69       538.89       463.40       364.82       184.35       202.78         10am       315.05       474.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77       525.00       339.72       277.78         11am       421.53       719.44       661.51       826.92       857.91       919.23       892.03       864.82       742.16       639.58       462.50       341.67         12pm       463.66       812.50       769.05       858.55       893.16       878.53       888.80       890.82       761.44       677.78       521.20       544.44         2pm       457.18       750.00       655.77       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         4pm       216.43       359.03       351.98       390.17       318.70       419.07       438.24       457.41       334.80       266.43       203.52       155.56       59m       52.55       70.83       184.53       184.83       206.31       222.02       239.29       157.		8am	25.70	86.11	146.43	266.88	359.83	366.03	316.58	267.13	250.82	168.98	46.20	33.33
Global       9am       165.51       250.00       369.05       464.96       547.76       572.49       555.69       538.89       463.40       364.82       184.35       202.78         10am       315.05       474.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77       525.00       339.72       277.78         11am       421.53       719.44       661.51       826.92       857.91       919.23       892.03       864.82       742.16       639.58       452.50       341.67         12pm       463.66       812.50       769.05       858.55       893.16       878.53       888.08       899.08       761.93       693.06       518.52       525.00         1pm       473.38       811.81       816.67       811.32       80.66       669.77       730.93       694.77       593.29       473.89       491.67         3pm       361.81       585.41       535.72       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         4pm       216.43       359.03       31.98       390.17       318.70       419.07       438.24       457.41       334.80<	Type b													
10am       315.05       474.31       556.75       676.28       733.98       755.88       713.58       671.29       636.77       525.00       339.72       277.78         11am       421.53       719.44       661.51       826.92       857.91       919.23       892.03       864.82       742.16       639.58       462.50       341.67         12pm       463.66       812.50       769.05       858.55       893.16       878.53       888.80       899.08       761.93       693.06       518.52       525.00         1pm       473.38       811.81       816.67       811.32       880.66       888.94       844.88       800.82       761.44       677.75       521.20       544.44         2pm       457.18       750.00       665.87       673.29       711.65       808.60       769.77       730.93       694.77       593.29       473.89       491.67         3pm       361.81       585.41       535.72       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         Diffuse       8am       17.13       56.95       54.36       108.76       125.94       125.11       143.91       159.72<	Global	9am	165.51	250.00	369.05	464.96	547.76	572.49	555.69	538.89	463.40	364.82	184.35	202.78
11am       421.53       719.44       661.51       826.92       857.91       919.23       892.03       864.82       742.16       639.58       462.50       341.67         12pm       463.66       812.50       769.05       858.55       893.16       878.53       888.80       899.08       761.93       693.06       518.52       525.00         1pm       473.38       811.81       816.67       811.32       880.66       888.94       844.88       800.82       761.44       677.78       521.20       544.44         2pm       457.18       700.0       665.87       673.29       711.65       808.60       769.77       730.93       694.77       593.29       473.89       491.67         3pm       361.81       585.41       535.72       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         pm       216.43       359.03       351.98       390.17       318.70       419.07       438.24       457.41       334.80       266.43       203.52       155.56         pm       52.55       70.83       184.53       108.76       128.91       128.11       143.91       159.72       124.02		10am	315.05	474.31	556.75	676.28	733.98	755.88	713.58	671.29	636.77	525.00	339.72	277.78
12pm       463.66       812.50       769.05       858.55       893.16       878.53       888.80       899.08       761.93       693.06       518.52       525.00         1pm       473.38       811.81       816.67       811.32       880.66       888.94       844.88       800.82       761.44       677.78       521.20       544.44         2pm       457.18       750.00       665.87       673.29       711.65       808.60       769.77       730.93       694.77       593.29       473.89       491.67         3pm       361.81       585.41       535.72       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         4pm       216.43       359.03       351.98       390.17       318.70       419.07       438.24       457.41       334.80       266.43       203.52       155.56         5pm       52.55       70.83       184.53       184.83       206.31       222.60       258.29       293.98       157.35       81.25       58.80       27.78         Diffuse       8am       17.13       56.95       54.36       108.76       125.94       128.11       143.91       159.72		11am	421.53	719.44	661.51	826.92	857.91	919.23	892.03	864.82	742.16	639.58	462.50	341.67
1pm       473.38       811.81       816.67       811.32       880.66       888.94       844.88       800.82       761.44       677.78       521.20       544.44         2pm       457.18       750.00       665.87       673.29       711.65       808.60       769.77       730.93       694.77       593.29       473.89       491.67         3pm       361.81       585.41       535.72       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         4pm       216.43       359.03       351.98       390.17       318.70       419.07       438.24       457.41       334.80       266.43       203.52       155.56         5pm       52.55       70.83       184.53       184.83       206.31       222.60       258.29       293.98       157.35       81.25       58.80       27.78         Diffuse       8am       17.13       56.95       54.36       108.76       125.94       128.11       143.91       159.72       124.02       86.34       27.13       8.33         9am       87.27       129.86       121.82       166.88       191.72       200.37       203.20       206.02 <t< td=""><td></td><td>12pm</td><td>463.66</td><td>812.50</td><td>769.05</td><td>858.55</td><td>893.16</td><td>878.53</td><td>888.80</td><td>899.08</td><td>761.93</td><td>693.06</td><td>518.52</td><td>525.00</td></t<>		12pm	463.66	812.50	769.05	858.55	893.16	878.53	888.80	899.08	761.93	693.06	518.52	525.00
2pm       457.18       750.00       665.87       673.29       711.65       808.60       769.77       730.93       694.77       593.29       473.89       491.67         3pm       361.81       585.41       535.72       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         4pm       216.43       359.03       351.98       390.17       318.70       419.07       438.24       457.41       334.80       266.43       203.52       155.56         5pm       52.55       70.83       184.53       184.83       206.31       222.60       258.29       293.98       157.35       81.25       58.80       27.78         Diffuse       8am       17.13       56.95       54.36       108.76       125.94       128.11       143.91       159.72       124.02       86.34       27.13       8.33         9am       87.27       129.86       121.82       166.88       191.72       200.37       203.20       206.02       167.98       139.82       97.59       91.67         10am       124.77       231.25       196.43       204.91       256.89       241.56       253.81       243.06 <td< td=""><td></td><td>1pm</td><td>473.38</td><td>811.81</td><td>816.67</td><td>811.32</td><td>880.66</td><td>888.94</td><td>844.88</td><td>800.82</td><td>761.44</td><td>677.78</td><td>521.20</td><td>544.44</td></td<>		1pm	473.38	811.81	816.67	811.32	880.66	888.94	844.88	800.82	761.44	677.78	521.20	544.44
3pm       361.81       585.41       535.72       446.37       355.13       542.84       590.17       637.50       527.29       448.61       357.59       327.78         4pm       216.43       359.03       351.98       390.17       318.70       419.07       438.24       457.41       334.80       266.43       203.52       155.56         5pm       52.55       70.83       184.53       184.83       206.31       222.60       258.29       293.98       157.35       81.25       58.80       27.78         Diffuse       8am       17.13       56.95       54.36       108.76       125.94       128.11       143.91       159.72       124.02       86.34       27.13       8.33         9am       87.27       129.86       121.82       166.88       191.72       200.37       203.20       206.02       167.98       139.82       97.59       91.67         10am       124.77       231.25       196.43       204.91       256.89       245.62       233.81       243.06       196.73       168.98       143.61       133.33         11am       148.84       235.41       226.59       213.25       300.27       321.73       278.92       236.11 <t< td=""><td></td><td>2pm</td><td>457.18</td><td>750.00</td><td>665.87</td><td>673.29</td><td>711.65</td><td>808.60</td><td>769.77</td><td>730.93</td><td>694.77</td><td>593.29</td><td>473.89</td><td>491.67</td></t<>		2pm	457.18	750.00	665.87	673.29	711.65	808.60	769.77	730.93	694.77	593.29	473.89	491.67
4pm       216.43       359.03       351.98       390.17       318.70       419.07       438.24       457.41       334.80       266.43       203.52       155.56         5pm       52.55       70.83       184.53       184.83       206.31       222.60       258.29       293.98       157.35       81.25       58.80       27.78         Diffuse       8am       17.13       56.95       54.36       108.76       125.94       128.11       143.91       159.72       124.02       86.34       27.13       8.33         9am       87.27       129.86       121.82       166.88       191.72       200.37       203.20       206.02       167.98       139.82       97.59       91.67         10am       124.77       231.25       196.43       204.91       256.89       264.56       253.81       243.06       196.73       168.98       143.61       133.33         11am       148.84       235.41       226.59       213.25       300.27       321.73       278.92       236.11       222.06       194.68       166.67       138.89         12pm       160.73       260.25       223.41       284.62       308.23       311.13       267.14       223.15       <		3pm	361.81	585.41	535.72	446.37	355.13	542.84	590.17	637.50	527.29	448.61	357.59	327.78
Spm         52.55         70.83         184.53         184.83         206.31         222.60         258.29         293.98         157.35         81.25         58.80         27.78           Diffuse         8am         17.13         56.95         54.36         108.76         125.94         128.11         143.91         159.72         124.02         86.34         27.13         8.33           9am         87.27         129.86         121.82         166.88         191.72         200.37         203.20         206.02         167.98         139.82         97.59         91.67           10am         124.77         231.25         196.43         204.91         256.89         264.56         253.81         243.06         196.73         168.98         143.61         133.33           11am         148.84         235.41         226.59         213.25         300.27         321.73         278.92         236.11         222.06         194.68         166.67         138.89           12pm         160.88         206.25         223.41         284.62         308.23         311.13         267.14         223.15         215.36         203.24         183.89         177.60         146.53         127.78         133.33		4pm	216.43	359.03	351.98	390.17	318.70	419.07	438.24	457.41	334.80	266.43	203.52	155.56
Diffuse         8am         17.13         56.95         54.36         108.76         125.94         128.11         143.91         159.72         124.02         86.34         27.13         8.33           9am         87.27         129.86         121.82         166.88         191.72         200.37         203.20         206.02         167.98         139.82         97.59         91.67           10am         124.77         231.25         196.43         204.91         256.89         264.56         253.81         243.06         196.73         168.98         143.61         133.33           11am         148.84         235.41         226.59         213.25         300.27         321.73         278.92         236.11         222.06         194.68         166.67         138.89           12pm         162.73         226.39         267.46         238.67         312.61         307.48         265.32         223.15         213.24         203.93         182.78         197.22           1pm         160.88         206.25         223.41         261.54         249.08         283.01         232.25         181.48         199.84         185.19         161.67         158.33           3pm         110.19		5pm	52.55	70.83	184.53	184.83	206.31	222.60	258.29	293.98	157.35	81.25	58.80	27.78
9am       87.27       129.86       121.82       166.88       191.72       200.37       203.20       206.02       167.98       139.82       97.59       91.67         10am       124.77       231.25       196.43       204.91       256.89       264.56       253.81       243.06       196.73       168.98       143.61       133.33         11am       148.84       235.41       226.59       213.25       300.27       321.73       278.92       236.11       222.06       194.68       166.67       138.89         12pm       162.73       226.39       267.46       238.67       312.61       307.48       265.32       223.15       213.24       203.93       182.78       197.22         1pm       160.88       206.25       223.41       246.20       308.23       311.13       267.14       223.15       215.36       203.24       183.89       175.00         2pm       151.62       192.36       223.41       261.54       249.08       283.01       232.25       181.48       199.84       185.19       161.67       158.33         3pm       110.19       150.00       212.70       186.54       124.30       190.00       195.69       201.39       173.69 </td <td>Diffuse</td> <td>8am</td> <td>17.13</td> <td>56.95</td> <td>54.36</td> <td>108.76</td> <td>125.94</td> <td>128.11</td> <td>143.91</td> <td>159.72</td> <td>124.02</td> <td>86.34</td> <td>27.13</td> <td>8.33</td>	Diffuse	8am	17.13	56.95	54.36	108.76	125.94	128.11	143.91	159.72	124.02	86.34	27.13	8.33
10am       124.77       231.25       196.43       204.91       256.89       264.56       253.81       243.06       196.73       168.98       143.61       133.33         11am       148.84       235.41       226.59       213.25       300.27       321.73       278.92       236.11       222.06       194.68       166.67       138.89         12pm       162.73       226.39       267.46       238.67       312.61       307.48       265.32       223.15       213.24       203.93       182.78       197.22         1pm       160.88       206.25       223.41       284.62       308.23       311.13       267.14       223.15       215.36       203.24       183.89       175.00         2pm       151.62       192.36       223.41       261.54       249.08       283.01       232.25       181.48       199.84       185.19       161.67       158.33         3pm       110.19       150.00       212.70       186.54       124.30       190.00       195.69       201.39       173.69       146.53       127.78       133.33         4pm       78.24       111.11       170.63       170.51       111.54       146.67       161.95       177.22       131.05		9am	87.27	129.86	121.82	166.88	191.72	200.37	203.20	206.02	167.98	139.82	97.59	91.67
11am       148.84       235.41       226.59       213.25       300.27       321.73       278.92       236.11       222.06       194.68       166.67       138.89         12pm       162.73       226.39       267.46       238.67       312.61       307.48       265.32       223.15       213.24       203.93       182.78       197.22         1pm       160.88       206.25       223.41       284.62       308.23       311.13       267.14       223.15       215.36       203.24       183.89       175.00         2pm       151.62       192.36       223.41       261.54       249.08       283.01       232.25       181.48       199.84       185.19       161.67       158.33         3pm       110.19       150.00       212.70       186.54       124.30       190.00       195.69       201.39       173.69       146.53       127.78       133.33         4pm       78.24       111.11       170.63       170.51       111.54       146.67       161.95       177.22       131.05       102.78       77.31       61.11         5pm       23.61       48.61       96.43       91.88       72.21       77.91       87.10       96.30       79.57		10am	124.77	231.25	196.43	204.91	256.89	264.56	253.81	243.06	196.73	168.98	143.61	133.33
12pm       162.73       226.39       267.46       238.67       312.61       307.48       265.32       223.15       213.24       203.93       182.78       197.22         1pm       160.88       206.25       223.41       284.62       308.23       311.13       267.14       223.15       215.36       203.24       183.89       175.00         2pm       151.62       192.36       223.41       261.54       249.08       283.01       232.25       181.48       199.84       185.19       161.67       158.33         3pm       110.19       150.00       212.70       186.54       124.30       190.00       195.69       201.39       173.69       146.53       127.78       133.33         4pm       78.24       111.11       170.63       170.51       111.54       146.67       161.95       177.22       131.05       102.78       77.31       61.11         5pm       23.61       48.61       96.43       91.88       72.21       77.91       87.10       96.30       79.57       40.28       17.96       11.11         Type c         Global       8am       23.89       35.48       51.39       208.33       204.34       204.85		11am	148.84	235.41	226.59	213.25	300.27	321.73	278.92	236.11	222.06	194.68	166.67	138.89
1pr       160.88       206.25       223.41       284.62       308.23       311.13       267.14       223.15       215.36       203.24       183.89       175.00         2pm       151.62       192.36       223.41       261.54       249.08       283.01       232.25       181.48       199.84       185.19       161.67       158.33         3pm       110.19       150.00       212.70       186.54       124.30       190.00       195.69       201.39       173.69       146.53       127.78       133.33         4pm       78.24       111.11       170.63       170.51       111.54       146.67       161.95       177.22       131.05       102.78       77.31       61.11         5pm       23.61       48.61       96.43       91.88       72.21       77.91       87.10       96.30       79.57       40.28       17.96       11.11         Type c         Global       8am       23.89       35.48       51.39       208.33       204.34       204.85       188.89       177.43       165.97       133.33       33.33       39.75         9am       90.00       123.89       94.44       352.08       360.42       217.52 <td< td=""><td></td><td>12pm</td><td>162.73</td><td>226.39</td><td>267.46</td><td>238.67</td><td>312.61</td><td>307.48</td><td>265.32</td><td>223.15</td><td>213.24</td><td>203.93</td><td>182.78</td><td>197.22</td></td<>		12pm	162.73	226.39	267.46	238.67	312.61	307.48	265.32	223.15	213.24	203.93	182.78	197.22
2pm       151.62       192.36       223.41       261.54       249.08       283.01       232.25       181.48       199.84       185.19       161.67       158.33         3pm       110.19       150.00       212.70       186.54       124.30       190.00       195.69       201.39       173.69       146.53       127.78       133.33         4pm       78.24       111.11       170.63       170.51       111.54       146.67       161.95       177.22       131.05       102.78       77.31       61.11         5pm       23.61       48.61       96.43       91.88       72.21       77.91       87.10       96.30       79.57       40.28       17.96       11.11         Type c         Global       8am       23.89       35.48       51.39       208.33       204.34       204.85       188.89       177.43       165.97       133.33       33.33       39.75         9am       90.00       123.89       94.44       352.08       360.42       217.52       344.44       320.135       295.83       211.11       155.56       158.48         10am       191.67       230.67       151.39       592.36       474.48       322.62       <		1pm	160.88	206.25	223.41	284.62	308.23	311.13	267.14	223.15	215.36	203.24	183.89	175.00
Jpm         110.19         150.00         212.70         186.54         124.30         190.00         195.69         201.39         173.69         146.53         127.78         133.33           4pm         78.24         111.11         170.63         170.51         111.54         146.67         161.95         177.22         131.05         102.78         77.31         61.11           5pm         23.61         48.61         96.43         91.88         72.21         77.91         87.10         96.30         79.57         40.28         17.96         11.11           Type c           Global         8am         23.89         35.48         51.39         208.33         204.34         204.85         188.89         177.43         165.97         133.33         33.33         39.75           9am         90.00         123.89         94.44         352.08         360.42         217.52         344.44         320.135         295.83         211.11         155.56         158.48           10am         191.67         230.67         151.39         592.36         474.48         322.62         372.22         387.85         403.48         258.33         289.81         238.50		2pm	151.62	192.36	223.41	261.54	249.08	283.01	232.25	181.48	199.84	185.19	161.67	158.33
4pm       78.24       111.11       170.63       170.51       111.54       146.67       161.95       177.22       131.05       102.78       77.31       61.11         5pm       23.61       48.61       96.43       91.88       72.21       77.91       87.10       96.30       79.57       40.28       17.96       11.11 <i>Type c</i> Global       8am       23.89       35.48       51.39       208.33       204.34       204.85       188.89       177.43       165.97       133.33       33.33       39.75         9am       90.00       123.89       94.44       352.08       360.42       217.52       344.44       320.135       295.83       211.11       155.56       158.48         10am       191.67       230.67       151.39       592.36       474.48       323.26       372.22       387.85       403.48       258.33       289.81       238.50         1am       97.167       328.00       210.46       522.55       522.64       507.72       427.77       200.28       205.20       102.87       727.78       205.26       403.48       228.20       205.26       403.48       228.20       205.26       403.48       258.33       289.81 <t< td=""><td></td><td>3pm</td><td>110.19</td><td>150.00</td><td>212.70</td><td>186.54</td><td>124.30</td><td>190.00</td><td>195.69</td><td>201.39</td><td>173 69</td><td>146.53</td><td>127.78</td><td>133 33</td></t<>		3pm	110.19	150.00	212.70	186.54	124.30	190.00	195.69	201.39	173 69	146.53	127.78	133 33
Type c       Global       8am       23.89       35.48       51.39       208.33       204.34       204.85       188.89       177.43       165.97       133.33       33.33       39.75         9am       90.00       123.89       94.44       352.08       360.42       217.52       344.44       320.135       295.83       211.11       155.56       158.48         10am       191.67       230.67       151.39       592.36       474.48       323.26       372.22       387.85       403.48       258.33       298.81       238.50         1am       271.67       323.00       210.44       622.22       555.56       522.64       507.72       427.77       200.28       205.29		4pm	78.24	111 11	170.63	170.51	111 54	146.67	161.95	177.22	131.05	102.78	77.31	61.11
<i>Type c</i> Global 8am 23.89 35.48 51.39 208.33 204.34 204.85 188.89 177.43 165.97 133.33 33.33 39.75 9am 90.00 123.89 94.44 352.08 360.42 217.52 344.44 320.135 295.83 211.11 155.56 158.48 10am 191.67 230.67 151.39 592.36 474.48 323.26 372.22 387.85 403.48 258.33 289.81 238.50 11am 271.67 328.09 210.46 652.32 550.55 56 552.64 557.672 427.78 200.82 205.01		5pm	23.61	48.61	96.43	91.88	72.21	77.91	87.10	96.30	79.57	40.28	17.96	11.11
Super         Sam         23.89         35.48         51.39         208.33         204.34         204.85         188.89         177.43         165.97         133.33         33.33         39.75           9am         90.00         123.89         94.44         352.08         360.42         217.52         344.44         320.135         295.83         211.11         155.56         158.48           10am         191.67         230.67         151.39         592.36         474.48         323.26         372.22         387.85         403.48         258.33         289.81         238.50           11am         271.67         328.09         210.42         252.55         522.64         550.72         427.77         200.28         205.51	Twne c	-												
9am 90.00 123.89 94.44 352.08 360.42 217.52 344.44 320.135 295.83 211.11 155.56 158.48 10am 191.67 230.67 151.39 592.36 474.48 323.26 372.22 387.85 403.48 258.33 289.81 238.50 11am 271.67 238.00 281.04 652.22 550.52 64 555.56 522.64 557.72 427.78 200.28 205.51	Global	8am	23.89	35.48	51.39	208.33	204.34	204.85	188.89	177.43	165.97	133.33	33.33	39.75
10am 191.67 230.67 151.39 592.36 474.48 323.26 372.22 387.85 403.48 258.33 289.81 238.50		9am	90.00	123.89	94.44	352.08	360.42	217.52	344 44	320 135	295.83	211.11	155 56	158 48
		10am	191.67	230.67	151.39	592.36	474.48	323.26	372.22	387.85	403.48	258.33	289.81	238.50
11am 2/1.07 556.07 261.74 022.22 550.55 580.51 505.56 552.64 559.72 427 78 399 38 295 91		11am	271.67	338.09	281.94	622.22	550.35	380.51	505.56	532.64	559.72	427.78	399.38	295.91

Table 2	(continued)
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Jan         Feb         Mar         Apr         May         June         July         Aug         Sep         Oct         Nov         Dec           12pm         306.67         399.70         434.72         783.34         668.76         447.54         541.67         529.165         516.66         702.78         428.70         304.           1pm         377.78         396.53         408.33         603.47         651.74         574.04         711.11         622.22         533.33         636.11         400.00         242.           2pm         359.44         392.25         475.00         604.86         600.35         600.71         577.78         559.725         541.67         433.33         367.28         260.           3pm         383.33         321.33         390.28         576.39         574.99         500.37         508.33         443.055         377.78         202.78         255.86         169.           4pm         155.56         157.83         226.38         311.25         284.38         293.83         263.89         290.28         316.67         94.44         124.69         88.3           5pm         30.00         38.83         61.11         188.89         225	Radiation	Time	Month											
12pm       306.67       399.70       434.72       783.34       668.76       447.54       541.67       529.165       516.66       702.78       428.70       304.         1pm       377.78       396.53       408.33       603.47       651.74       574.04       711.11       622.22       533.33       636.11       400.00       242.         2pm       359.44       392.25       475.00       604.86       600.35       600.71       577.78       559.725       541.67       433.33       367.28       260.         3pm       383.33       321.33       390.28       576.39       574.99       500.37       508.33       443.055       377.78       202.78       255.86       169.         4pm       155.56       157.83       226.38       331.25       284.38       293.83       263.89       290.28       316.67       94.44       124.69       88.3       5pm       30.00       38.83       61.11       188.89       229.34       268.86       225.00       180.21       135.42       50.00       32.10       23.8         Diffuse       8am       19.89       23.26       25.00       153.47       141.97       130.48       55.56       97.64       139.72       1			Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1pm       377.78       396.53       408.33       603.47       651.74       574.04       711.11       622.22       533.33       636.11       400.00       242.         2pm       359.44       392.25       475.00       604.86       600.35       600.71       577.78       559.725       541.67       433.33       367.28       260.         3pm       383.33       321.33       390.28       576.39       574.99       500.37       508.33       443.055       377.78       202.78       255.86       169.         4pm       155.56       157.83       226.38       331.25       284.38       293.83       263.89       290.28       316.67       94.44       124.69       88.3         5pm       30.00       38.83       61.11       188.89       229.34       268.86       225.00       180.21       135.42       50.00       32.10       23.8         Diffuse       8am       19.89       23.26       25.00       153.47       141.97       130.48       55.56       97.64       139.72       100       24.07       25.0         9am       73.34       79.75       44.44       228.47       183.51       138.55       91.67       144.79       197.92		12pm	306.67	399.70	434.72	783.34	668.76	447.54	541.67	529.165	516.66	702.78	428.70	304.76
2pm       359.44       392.25       475.00       604.86       600.35       600.71       577.78       559.725       541.67       433.33       367.28       260.         3pm       383.33       321.33       390.28       576.39       574.99       500.37       508.33       443.055       377.78       202.78       255.86       169.         4pm       155.56       157.83       226.38       331.25       284.38       293.83       263.89       290.28       316.67       94.44       124.69       88.3         5pm       30.00       38.83       61.11       188.89       229.34       268.86       225.00       180.21       135.42       50.00       32.10       23.8         Diffuse       8am       19.89       23.26       25.00       153.47       141.97       130.48       55.56       97.64       139.72       100       24.07       25.0         9am       73.34       79.75       44.44       228.47       183.51       138.55       91.67       144.79       197.92       147.22       100.62       90.61         10am       148.33       124.97       63.89       325.00       265.45       205.90       238.89       271.88       304.86		1pm	377.78	396.53	408.33	603.47	651.74	574.04	711.11	622.22	533.33	636.11	400.00	242.92
3pm       383.33       321.33       390.28       576.39       574.99       500.37       508.33       443.055       377.78       202.78       255.86       169.         4pm       155.56       157.83       226.38       331.25       284.38       293.83       263.89       290.28       316.67       94.44       124.69       88.3         5pm       30.00       38.83       61.11       188.89       229.34       268.86       225.00       180.21       135.42       50.00       32.10       23.8         Diffuse       8am       19.89       23.26       25.00       153.47       141.97       130.48       55.56       97.64       139.72       100       24.07       25.0         9am       73.34       79.75       44.44       228.47       183.51       138.55       91.67       144.79       197.92       147.22       100.62       99.6         10am       148.33       124.97       63.89       325.00       265.45       205.90       238.89       271.88       304.86       258.33       143.83       150.         11am       201.66       164.23       80.56       375.00       308.68       242.36       219.44       296.52       373.61		2pm	359.44	392.25	475.00	604.86	600.35	600.71	577.78	559.725	541.67	433.33	367.28	260.59
4pm       155.56       157.83       226.38       331.25       284.38       293.83       263.89       290.28       316.67       94.44       124.69       88.3         5pm       30.00       38.83       61.11       188.89       229.34       268.86       225.00       180.21       135.42       50.00       32.10       23.8         Diffuse       8am       19.89       23.26       25.00       153.47       141.97       130.48       55.56       97.64       139.72       100       24.07       25.0         9am       73.34       79.75       44.44       228.47       183.51       138.55       91.67       144.79       197.92       147.22       100.62       99.6         10am       148.33       124.97       63.89       325.00       265.45       205.90       238.89       271.88       304.86       258.33       143.83       150.         11am       201.66       164.23       80.56       375.00       308.68       242.36       219.44       296.52       373.61       350.00       187.35       186.         12pm       257.22       227.73       166.67       355.56       320.31       285.06       308.33       331.6       354.86		3pm	383.33	321.33	390.28	576.39	574.99	500.37	508.33	443.055	377.78	202.78	255.86	169.61
5pm         30.00         38.83         61.11         188.89         229.34         268.86         225.00         180.21         135.42         50.00         32.10         23.8           Diffuse         8am         19.89         23.26         25.00         153.47         141.97         130.48         55.56         97.64         139.72         100         24.07         25.0           9am         73.34         79.75         44.44         228.47         183.51         138.55         91.67         144.79         197.92         147.22         100.62         99.6           10am         148.33         124.97         63.89         325.00         265.45         205.90         238.89         271.88         304.86         258.33         143.83         150.           11am         201.66         164.23         80.56         375.00         308.68         242.36         219.44         296.52         373.61         350.00         187.35         186.           12pm         257.22         227.73         166.67         355.56         320.31         285.06         308.33         331.6         354.86         372.22         243.52         191.           1pm         281.11         261.95		4pm	155.56	157.83	226.38	331.25	284.38	293.83	263.89	290.28	316.67	94.44	124.69	88.34
Diffuse         8am         19.89         23.26         25.00         153.47         141.97         130.48         55.56         97.64         139.72         100         24.07         25.0           9am         73.34         79.75         44.44         228.47         183.51         138.55         91.67         144.79         197.92         147.22         100.62         99.6           10am         148.33         124.97         63.89         325.00         265.45         205.90         238.89         271.88         304.86         258.33         143.83         150.           11am         201.66         164.23         80.56         375.00         308.68         242.36         219.44         296.52         373.61         350.00         187.35         186.           12pm         257.22         227.73         166.67         355.56         320.31         285.06         308.33         331.6         354.86         372.22         243.52         191.           1pm         281.11         261.95         288.89         423.61         394.62         365.63         427.78         389.93         352.08         386.11         238.89         152.           2pm         212.78         258.06 <td></td> <td>5pm</td> <td>30.00</td> <td>38.83</td> <td>61.11</td> <td>188.89</td> <td>229.34</td> <td>268.86</td> <td>225.00</td> <td>180.21</td> <td>135.42</td> <td>50.00</td> <td>32.10</td> <td>23.85</td>		5pm	30.00	38.83	61.11	188.89	229.34	268.86	225.00	180.21	135.42	50.00	32.10	23.85
9am       73.34       79.75       44.44       228.47       183.51       138.55       91.67       144.79       197.92       147.22       100.62       99.6         10am       148.33       124.97       63.89       325.00       265.45       205.90       238.89       271.88       304.86       258.33       143.83       150.         11am       201.66       164.23       80.56       375.00       308.68       242.36       219.44       296.52       373.61       350.00       187.35       186.         12pm       257.22       227.73       166.67       355.56       320.31       285.06       308.33       331.6       354.86       372.22       243.52       191.         1pm       281.11       261.95       288.89       423.61       394.62       365.63       427.78       389.93       352.08       386.11       238.89       152.         2pm       212.78       258.06       363.89       313.19       347.91       382.62       385.56       352.5       319.44       316.67       227.78       163.3         3pm       160.00       217.78       372.22       277.78       298.24       318.71       346.11       309.51       272.92       19	Diffuse	8am	19.89	23.26	25.00	153.47	141.97	130.48	55.56	97.64	139.72	100	24.07	25.00
10am       148.33       124.97       63.89       325.00       265.45       205.90       238.89       271.88       304.86       258.33       143.83       150.         11am       201.66       164.23       80.56       375.00       308.68       242.36       219.44       296.52       373.61       350.00       187.35       186.         12pm       257.22       227.73       166.67       355.56       320.31       285.06       308.33       331.6       354.86       372.22       243.52       191.         1pm       281.11       261.95       288.89       423.61       394.62       365.63       427.78       389.93       352.08       386.11       238.89       152.         2pm       212.78       258.06       363.89       313.19       347.91       382.62       385.56       352.5       319.44       316.67       227.78       163.3         3pm       160.00       217.78       372.22       277.78       298.24       318.71       346.11       309.51       272.92       191.67       169.45       106.         4pm       76.67       96.25       113.89       226.39       206.77       187.15       211.11       235.07       259.03		9am	73.34	79.75	44.44	228.47	183.51	138.55	91.67	144.79	197.92	147.22	100.62	99.67
11am       201.66       164.23       80.56       375.00       308.68       242.36       219.44       296.52       373.61       350.00       187.35       186.         12pm       257.22       227.73       166.67       355.56       320.31       285.06       308.33       331.6       354.86       372.22       243.52       191.         1pm       281.11       261.95       288.89       423.61       394.62       365.63       427.78       389.93       352.08       386.11       238.89       152.         2pm       212.78       258.06       363.89       313.19       347.91       382.62       385.56       352.5       319.44       316.67       227.78       163.3         3pm       160.00       217.78       372.22       277.78       298.24       318.71       346.11       309.51       272.92       191.67       169.45       106.         4pm       76.67       96.25       113.89       226.39       206.77       187.15       211.11       235.07       259.03       94.44       97.22       55.5         5pm       18.33       35.29       72.22       115.28       143.26       171.25       202.78       154.31       105.83       41.67		10am	148.33	124.97	63.89	325.00	265.45	205.90	238.89	271.88	304.86	258.33	143.83	150.00
12pm       257.22       227.73       166.67       355.56       320.31       285.06       308.33       331.6       354.86       372.22       243.52       191.         1pm       281.11       261.95       288.89       423.61       394.62       365.63       427.78       389.93       352.08       386.11       238.89       152.         2pm       212.78       258.06       363.89       313.19       347.91       382.62       385.56       352.5       319.44       316.67       227.78       163.         3pm       160.00       217.78       372.22       277.78       298.24       318.71       346.11       309.51       272.92       191.67       169.45       106.         4pm       76.67       96.25       113.89       226.39       206.77       187.15       211.11       235.07       259.03       94.44       97.22       55.5         5pm       18.33       35.29       72.22       115.28       143.26       171.25       202.78       154.31       105.83       41.67       25.31       15.0         Type d         Global       8am       29.63       56.95       77.78       127.78       177.78       186.11       19		11am	201.66	164.23	80.56	375.00	308.68	242.36	219.44	296.52	373.61	350.00	187.35	186.11
lpm         281.11         261.95         288.89         423.61         394.62         365.63         427.78         389.93         352.08         386.11         238.89         152.           2pm         212.78         258.06         363.89         313.19         347.91         382.62         385.56         352.5         319.44         316.67         227.78         163.           3pm         160.00         217.78         372.22         277.78         298.24         318.71         346.11         309.51         272.92         191.67         169.45         106.           4pm         76.67         96.25         113.89         226.39         206.77         187.15         211.11         235.07         259.03         94.44         97.22         55.5           5pm         18.33         35.29         72.22         115.28         143.26         171.25         202.78         154.31         105.83         41.67         25.31         15.0		12pm	257.22	227.73	166.67	355.56	320.31	285.06	308.33	331.6	354.86	372.22	243.52	191.67
2pm         212.78         258.06         363.89         313.19         347.91         382.62         385.56         352.5         319.44         316.67         227.78         163.           3pm         160.00         217.78         372.22         277.78         298.24         318.71         346.11         309.51         272.92         191.67         169.45         106.           4pm         76.67         96.25         113.89         226.39         206.77         187.15         211.11         235.07         259.03         94.44         97.22         55.5           5pm         18.33         35.29         72.22         115.28         143.26         171.25         202.78         154.31         105.83         41.67         25.31         15.0           Type d           Global         8am         29.63         56.95         77.78         127.78         177.78         186.11         194.44         163.89         41.67         39.45         37.22         25.0		1pm	281.11	261.95	288.89	423.61	394.62	365.63	427.78	389.93	352.08	386.11	238.89	152.78
3pm         160.00         217.78         372.22         277.78         298.24         318.71         346.11         309.51         272.92         191.67         169.45         106.           4pm         76.67         96.25         113.89         226.39         206.77         187.15         211.11         235.07         259.03         94.44         97.22         55.5           5pm         18.33         35.29         72.22         115.28         143.26         171.25         202.78         154.31         105.83         41.67         25.31         15.0           Type d           Global         8am         29.63         56.95         77.78         127.78         177.78         186.11         194.44         163.89         41.67         39.45         37.22         25.0		2pm	212.78	258.06	363.89	313.19	347.91	382.62	385.56	352.5	319.44	316.67	227.78	163.89
4pm         76.67         96.25         113.89         226.39         206.77         187.15         211.11         235.07         259.03         94.44         97.22         55.5           5pm         18.33         35.29         72.22         115.28         143.26         171.25         202.78         154.31         105.83         41.67         25.31         15.0           Type d           Global         8am         29.63         56.95         77.78         127.78         177.78         186.11         194.44         163.89         41.67         39.45         37.22         25.0		3pm	160.00	217.78	372.22	277.78	298.24	318.71	346.11	309.51	272.92	191.67	169.45	106.67
5pm         18.33         35.29         72.22         115.28         143.26         171.25         202.78         154.31         105.83         41.67         25.31         15.0           Type d         Global         8am         29.63         56.95         77.78         127.78         177.78         186.11         194.44         163.89         41.67         39.45         37.22         25.0		4pm	76.67	96.25	113.89	226.39	206.77	187.15	211.11	235.07	259.03	94.44	97.22	55.56
<i>Type d</i> Global 8am 29.63 56.95 77.78 127.78 177.78 186.11 194.44 163.89 41.67 39.45 37.22 25.0		5pm	18.33	35.29	72.22	115.28	143.26	171.25	202.78	154.31	105.83	41.67	25.31	15.00
Global 8am 29.63 56.95 77.78 127.78 177.78 186.11 194.44 163.89 41.67 39.45 37.22 25.0	Type d													
	Global	8am	29.63	56.95	77.78	127.78	177.78	186.11	194.44	163.89	41.67	39.45	37.22	25.00
9am 148.15 168.06 205.56 241.67 277.78 263.89 250.00 191.67 100.00 129.16 158.33 112.		9am	148.15	168.06	205.56	241.67	277.78	263.89	250.00	191.67	100.00	129.16	158.33	112.22
10am 258.89 279.17 369.44 394.44 419.44 369.44 319.44 449.44 219.44 294.44 369.44 225.		10am	258.89	279.17	369.44	394.44	419.44	369.44	319.44	449.44	219.44	294.44	369.44	225.00
11am 351.85 286.81 391.67 188.89 489.45 511.39 533.33 544.44 438.89 406.94 375.00 438.		11am	351.85	286.81	391.67	188.89	489.45	511.39	533.33	544.44	438.89	406.94	375.00	438.89
12pm 361.11 364.58 366.67 550.00 733.33 611.11 488.89 688.33 641.67 527.78 413.89 531.		12pm	361.11	364.58	366.67	550.00	733.33	611.11	488.89	688.33	641.67	527.78	413.89	531.11
1pm 300.00 323.61 283.33 933.33 933.33 708.33 483.33 593.89 575.00 483.33 391.67 491.		1pm	300.00	323.61	283.33	933.33	933.33	708.33	483.33	593.89	575.00	483.33	391.67	491.67
2pm 286.11 287.50 283.33 583.33 883.33 655.55 427.78 569.44 491.67 405.56 319.44 388.		2pm	286.11	287.50	283.33	583.33	883.33	655.55	427.78	569.44	491.67	405.56	319.44	388.89
3pm 171.30 221.53 200.00 427.78 655.56 590.28 325.00 375.00 341.67 312.50 283.33 304.		3pm	171.30	221.53	200.00	427.78	655.56	590.28	325.00	375.00	341.67	312.50	283.33	304.44
4pm 80.56 100.00 144.44 119.44 94.44 184.72 275.00 197.22 277.78 188.89 100.00 105.		4pm	80.56	100.00	144.44	119.44	94.44	184.72	275.00	197.22	277.78	188.89	100.00	105.56
5pm 20.37 42.36 47.22 77.78 108.34 141.67 175.00 116.67 88.89 60.56 32.22 16.6		5pm	20.37	42.36	47.22	77.78	108.34	141.67	175.00	116.67	88.89	60.56	32.22	16.67
Diffuse 8am 25.48 46.53 67.67 98.39 129.11 158.19 180.56 137.67 38.89 36.11 33.33 21.0	Diffuse	8am	25.48	46.53	67.67	98.39	129.11	158.19	180.56	137.67	38.89	36.11	33.33	21.00
9am 127.41 147.92 178.84 186.09 193.34 224.31 238.89 161.00 97.22 123.33 129.44 107.		9am	127.41	147.92	178.84	186.09	193.34	224.31	238.89	161.00	97.22	123.33	129.44	107.22
10am 222.65 243.75 321.41 303.72 286.03 314.02 313.89 377.53 216.67 256.94 297.22 213.		10am	222.65	243.75	321.41	303.72	286.03	314.02	313.89	377.53	216.67	256.94	297.22	213.89
11am 302.59 258.33 340.75 145.45 439.25 434.68 363.89 457.33 406.11 352.22 298.33 336.		11am	302.59	258.33	340.75	145.45	439.25	434.68	363.89	457.33	406.11	352.22	298.33	336.89
12pm 310.55 260.42 246.50 423.50 600.50 519.44 441.67 578.2 507.78 415.83 323.89 350.		12pm	310.55	260.42	246.50	423.50	600.50	519.44	441.67	578.2	507.78	415.83	323.89	350.00
1pm 258.00 293.75 190.91 718.66 779.41 602.08 462.78 498.87 501.67 380.00 258.33 350.		1pm	258.00	293.75	190.91	718.66	779.41	602.08	462.78	498.87	501.67	380.00	258.33	350.00
2pm 246.05 258.33 319.00 449.16 579.32 557.22 416.67 478.33 488.89 358.61 228.33 230.		2pm	246.05	258.33	319.00	449.16	579.32	557.22	416.67	478.33	488.89	358.61	228.33	230.00
3pm 147.32 184.03 246.50 329.39 412.28 501.74 322.22 315.00 338.89 256.06 173.22 258.		3pm	147.32	184.03	246.50	329.39	412.28	501.74	322.22	315.00	338.89	256.06	173.22	258.89
4pm 69.28 88.19 125.66 91.97 58.28 157.01 272.22 165.66 230.56 163.89 97.22 100.		4pm	69.28	88.19	125.66	91.97	58.28	157.01	272.22	165.66	230.56	163.89	97.22	100.56
5pm 17.52 38.20 41.08 59.89 78.70 120.42 172.22 98.00 86.11 57.77 29.44 13.8		5pm	17.52	38.20	41.08	59.89	78.70	120.42	172.22	98.00	86.11	57.77	29.44	13.89

thickness of atmosphere ( $\varepsilon$ ) at a specific point in time to the optical thickness of atmosphere when sun is at zenith,  $\theta_Z$  is zenith angle in degree and  $I_N$  is normal terrestrial solar radiation at ground level in W/m<sup>2</sup> and

$$I_{\rm HD} = K_1 (I_{\rm ON} - I_{\rm N}) \cos(\theta_Z) + K_2, \tag{2}$$

where  $I_{\rm HD}$  is terrestrial diffuse solar radiation on horizontal surface at ground level in W/m<sup>2</sup>,  $T_{\rm R}$  is cloudiness/haziness factor (dimensionless),  $\alpha$  is atmospheric transmittance,  $K_1$ 

Table 3 Parameters of Joshi and Tiwari on horizontal surface for sunshine hours = 10 for all four type of days

Type of d	ay Parameter	s Month											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
a	$T_{\rm R}$	1.45	5.37	3.31	4.25	5.41	3.63	5.77	6.45	4.06	2.61	4.03	0.72
	α	0.33	-0.36	-0.03	-0.03	-0.12	0.08	-0.09	-0.23	0.03	0.20	-0.37	0.53
	$K_1$	0.37	0.63	0.69	0.37	0.51	0.33	0.17	0.37	0.46	0.43	0.66	0.33
	$K_2$	-6.14	-82.86	-94.01	-10.95	-79.57	-13.73	68.06	-42.79	-60.27	-47.83	-37.00	-6.60
b	$T_{\rm R}$	3.09	6.98	4.65	6.92	5.86	6.82	7.40	7.58	6.41	4.04	0.04	0.35
	α	0.38	-0.48	0.23	0.06	0.29	0.11	0.00	-0.13	-0.04	0.19	1.16	1.00
	$K_1$	0.39	0.83	0.59	0.42	0.32	0.63	0.48	0.38	0.48	0.52	0.37	0.41
	$K_2$	-23.08	8-110.23	-107.74	-49.61	0.26	-167.86	-80.06	-13.91	-66.64	-62.52	-14.63	-12.20
с	$T_{\rm R}$	2.35	6.59	6.31	7.57	8.69	8.00	9.72	8.23	7.36	5.02	1.86	0.76
	α	1.64	0.86	1.35	0.57	0.61	0.81	0.69	0.90	0.99	1.49	1.47	1.98
	$K_1$	0.41	0.42	0.48	0.54	0.50	0.39	0.56	0.49	0.44	0.52	0.41	0.31
	$K_2$	-37.87	-85.68	-180.45	-120.38	-146.97	-87.44	-228.91	-147.96	-62.10	-93.64	-40.07	-12.15
d	$T_{\rm R}$	1.69	1.36	7.52	9.09	9.48	10.79	10.93	8.54	8.16	7.75	3.78	2.44
	α	2.63	2.97	1.87	1.35	1.13	1.56	3.08	1.71	3.15	1.70	1.74	2.04
	$K_1$	0.43	0.36	0.35	0.62	0.92	0.80	0.45	0.75	0.67	0.55	0.48	0.63
	$K_2$	-41.27	-44.68	-65.17	-254.24	-467.30	-421.63	-129.49	-356.92	-261.85	5 -119.53	8 - 49.16	-64.02



Fig. 2. The variation of annual solar radiation for clear day with inclination.

is perturbation factor (dimensionless) and  $K_2$  is background diffuse radiation (W/m<sup>2</sup>). The values of  $T_{\rm R}$ ,  $\alpha$ ,  $K_1$  and  $K_2$  for each case and month have been given in Table 3.

The beam and diffuse radiation on horizontal surface obtained from Eqs. (1) and (2) are converted on an inclined PV/T module by using Liu and Jordan formula for optimized inclination [24,25]. The variation of annual solar radiation for clear day with inclination is shown in Fig. 2. It is seen that the maximum solar energy is available for  $30-40^{\circ}$  inclination and hence the optimum inclination has been used to evaluate energy and exergy analysis of PV/T system.

### 2.2. Thermal modeling of the hybrid PV/T air collector

In order to write the energy balance equation for each component of a PV/T air collector as shown in the Fig. 1b, the following assumptions have been made:

- (i) The system is in quasi-steady-state condition.
- (ii) The transmittivity of EVA is approximately 100 percent.
- (iii) The temperature variation along the thickness is negligible.
- (iv) The airflow through duct is uniform for the forced mode of operation for streamline flow and
- (v) The PV/T module in inclined at average optimum value of 35<sup>0</sup>, which is about equal to latitude of Srinagar.

#### 2.3. Energy balance

Referring to Figs. 1a and b and following [12], the energy balance equations are as follows:

For the PV module:

$$\tau [\alpha_{\rm c} I(t)\beta_{\rm c} + (1 - \beta_{\rm c})\alpha_{\rm T} I(t)]bdx = [U_{\rm t}(T_{\rm c} - T_{\rm a}) + U_{\rm T}(T_{\rm c} - T_{\rm bs})]bdx + \eta_{\rm c} I(t)\beta_{\rm c}bdx.$$

$$-\frac{1}{2} - \frac{1}{3} - \frac{1}{4} - \frac{1}{5} - \frac{1}{3} - \frac{1}{3$$

Five elements of the Eq. (3) can be described as

- 1 the rate of solar energy received by solar cell after transmission;
- 2 the rate of solar energy absorbed by tedlar after transmission from EVA;
- 3 the rate of heat lost from solar cell to ambient through glass cover;
- 4 the rate of heat lost from solar cell to back surface of the tedlar for elemental area 'bdx' and
- 5 the rate of electrical energy available from solar cell of PV module. For the back surface of the Tedlar:

Energy balance for back surface of the tedlar is as follows:

where

6 the rate of heat transfer from back surface to flowing air for elemental area 'bdx'. For the air flowing below the tedlar (air duct, Figs. 1b and c):

$$\frac{h_{\rm T}(T_{\rm bs} - T_{\rm air})bdx}{6} = \frac{m_{\rm a}C_{\rm a} ({\rm d}T_{\rm air}/{\rm d}x) \,{\rm d}x + U_{\rm b}(T_{\rm air} - T_{\rm a})bdx,}{\frac{1}{8}}$$
(5)

where

Table 5

- 7 the heat carried away with the flowing air and
- 8 the rate of heat transfer from flowing air to ambient for elemental area 'bdx'

An expression for the temperature of the flowing air below the tedlar can be obtained by integrating Eq. (5) with the initial condition  $T_{air} = T_{airin}$ , at x = 0 as

$$T_{\rm air} = \frac{h_{\rm p1} h_{\rm p2}(\alpha \tau)_{\rm eff} I(t)}{U_{\rm L}} \left( 1 - e^{\frac{-bU_{\rm L}}{m_{\rm a}c_{\rm a}}x} \right) + T_a \left( 1 - e^{\frac{-bU_{\rm L}}{m_{\rm a}c_{\rm a}}x} \right) + T_{\rm airin} e^{\frac{-bU_{\rm L}}{m_{\rm a}c_{\rm a}}x}.$$
 (6)

Eq. (6) can be used to get average air temperature and then solar cell and the back surface temperature from Eqs. (3) and (4), respectively.

The outlet air temperature  $(T_{airout})$  of the flowing air below the tedlar can be obtained from the above equation as

$$T_{\text{airout}} = T_{\text{air}} \bigg|_{x=L} \bigg[ \frac{h_{\text{pl}} h_{\text{p2}}(\alpha \tau)_{\text{eff}} I(t)}{U_{\text{L}}} + I(t) \bigg] \bigg( 1 - e^{\frac{-bU_{\text{L}}}{m_{\text{a}}c_{\text{a}}} \text{L}} \bigg) + T_{\text{airin}} e^{\frac{-bU_{\text{L}}}{m_{\text{a}}c_{\text{a}}} \text{L}}.$$
 (7)

The rate of useful thermal energy obtained from the PV/T air collector is thus obtained as [12]

$$\dot{q}_{\rm u} = \dot{m}_{\rm a} c_{\rm a} (T_{\rm airout} - T_{\rm airin}) = \frac{\dot{m}_{\rm a} c_{\rm a}}{U_{\rm L}} \left\{ h_{\rm p1} h_{\rm p2} (\alpha \tau)_{\rm eff} I(t) - U_{\rm L} (T_{\rm airin} - T_{\rm a}) \right\} \left( 1 - \mathrm{e}^{\frac{-bU_{\rm L}}{m_{\rm a} c_{\rm a}}} L \right),$$
(8)

Table 4 The average number of days in different months under different weather types for Srinagar climatic condition

Type of day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
a	2	7	9	10	17	14	10	10	14	9	5	3
b	15	10	10	13	9	10	10	9	8	8	12	8
с	12	9	9	6	4	5	7	9	5	9	10	19
d	2	2	3	1	1	1	1	3	3	3	3	1

Average ambient temperature (°C) at Srinagar for January–December (IMD)

Time	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
8am	-2.0	2.8	6.3	15.6	16.1	21.0	21.1	19.3	17.2	6.4	1.5	1.8
9am	-2.2	2.8	4.8	15.0	15.6	20.8	20.8	18.9	16.7	6.0	1.0	1.9
10am	-2.2	2.5	4.0	14.3	15.1	20.3	20.3	18.1	16.0	6.0	0.5	1.7
11am	-2.4	2.5	4.3	14.3	15.8	20.6	20.3	18.1	15.7	6.0	0.5	1.6
12pm	-2.3	2.5	4.8	14.3	17.6	22.7	20.4	18.3	17.0	6.5	1.0	1.7
1pm	-2.1	2.5	7.2	15.0	20.8	25.2	22.9	20.6	20.9	10.4	3.0	1.0
2pm	-1.6	3.4	7.6	15.0	21.8	26.0	25.0	23.0	23.8	13.9	6.0	2.7
3pm	-1.6	5.3	10.1	15.1	25.3	26.7	25.5	25.2	25.9	17.0	8.3	4.7
4pm	-0.6	5.5	9.9	17.1	26.4	28.6	27.3	26.7	27.4	19.4	10.5	6.5
5pm	-0.2	7.5	10.8	17.0	27.8	30.1	28.1	27.6	28.8	21.9	11.5	8.4

where  $U_{\rm L} = U_{\rm tair} + U_{\rm b}$ ,  $h_{\rm p1} = U_{\rm T}/(U_{\rm t} + U_{\rm T})$ , is the penalty factor due to the glass cover of a PV module, and  $h_{\rm p2} = h_{\rm T}/(U_{\rm tT} + h_{\rm T})$ , is the penalty factor due to the tedlar of a PV module,

$$(\alpha \tau)_{\rm eff} = \tau \{ \alpha_{\rm c} \beta_{\rm c} + \alpha_{\rm T} (1 - \beta_{\rm c}) - \eta_{\rm c} \beta_{\rm c} \} I(t).$$

Following Bosanac et al. the rate of exergy obtained from the PV/T air collector is thus obtained as [1]

$$\dot{q}_{\text{exergy}} = \dot{q}_{\text{u}} \left[ 1 - \frac{(T_0 + 273)}{293 + \Delta T} \right],$$
(9)

where  $T_0$  is the reference ambient temperature = 20 °C (293 K) and  $\Delta T$  is the difference between the ambient temperature and the collector outlet temperature.



Fig. 3. (a) Reproduced beam and diffuse radiation with ambient temperature for January at Srinagar. (b) Reproduced beam and diffuse radiation with ambient temperature for June at Srinagar.

The equivalent rate of thermal energy for conversion factor of 0.38 for thermal power plant of PV module will be as follows:

$$\dot{q}_{\rm eth} = \frac{\eta_0 \{1 - \beta \Delta T\} I(t) bL}{0.38}.$$
(10)

Here  $\beta = 0.0045$  per °C.

The overall efficiency of the PV/T collector is [12]

$$\eta_{\rm ov} = \frac{\sum_{i=1}^{T} [\dot{q}_{\rm eth} + \dot{q}_{\rm u}]}{\sum_{i=1}^{T} I(t) bL},\tag{11}$$

where T is the sunshine hours.

Eq. (11) can also be written as

$$\eta_{\rm ov} = \frac{\eta_{\rm o} \{1 - \beta \Delta T\}}{0.38} + \eta_{\rm th}.$$
(12)



Fig. 4. (a) Predicted temperatures (°C) for a PV/T system in January at Srinagar. (b) Predicted temperatures (°C) for a PV/T system in June at Srinagar.

The exergy efficiency of The PV/T air collector will be determined as

$$\eta_{\text{exergyov}} = \eta_{\text{o}}[1 - \beta \Delta T] + \eta_{\text{th}} \left[ 1 - \frac{(T_0 + 273)}{293 + \Delta T} \right],$$
(13)

The monthly thermal energy and exergy have been evaluated by using the data of Tables 4 and 5 for all cases are as follows:

$$\dot{Q}_{\rm u} = \sum_{i=1}^{4} n_i \dot{q}_{\rm ui}.$$
(14)

Here  $\dot{q}_{ui}$  can be evaluated from Eq. (8) for each case for given  $n_i$  for each month. *i* stands for type of the days in month (e.g. i = 1 means 'a' type weather condition, i = 2 means 'b' type weather condition). Similarly monthly exergy can be obtained [26]. The yearly thermal energy and exergy can be evaluated by summing monthly thermal energy and exergy.



Fig. 5. (a) Useful thermal, electrical and total energy  $(W/m^2)$  and energy efficiency for January at Srinagar. (b) Useful thermal, electrical and total energy  $(W/m^2)$  and energy efficiency for June at Srinagar.

#### 3. Numerical results

Eqs. (1) and (2) have been used to evaluate the beam and diffuse radiation for all cases and each month by using the parameters of Table 3. The hourly variation of beam and diffuse radiation and ambient temperature for typical day for January and June for case (a) has been shown in Figs. 3. The total radiation on inclined PV module is obtained by using Liu and Jordon formula. The average data of total and diffuse radiation given in Table 2a is used to determine the beam radiation and the parameters of Table 3 are used to reproduce the average beam and diffuse radiation varies from a minimum value of  $50 \text{ W/m}^2$  at 8 am and 5 pm to a maximum value of  $450 \text{ W/m}^2$  at 12 pm for the month of January (Fig. 3a) where as it varies from a minimum value of  $520 \text{ W/m}^2$  at 8 am and 5 pm to a maximum value of  $320 \text{ W/m}^2$  at 8 am and 5 pm to a maximum value of June (Fig. 3b).

Eqs. (3–6) have been used to evaluate the hourly variation of average air, solar cell, back surface and outlet air temperatures for typical day for the month of January and June and



Fig. 6. (a) Electrical, thermal and total exergy and exegy efficiency for January at Srinagar. (b) Electrical, thermal and total exergy and exegy efficiency for June at Srinagar.

the results have been shown in Figs. 4. Computations were carried out for climatic data of Figs. 3 and design parameters of Table 1. It is observed that there is significant increase in outlet air temperature which gives an additional thermal energy in addition to electrical energy for both winter and summer climatic conditions. The average air temperature is slightly lower than outlet air temperature as expected. The solar cell and back surface temperature is significantly higher than the outlet air temperature. The outlet air temperature can be further increased by reducing flow velocity of air in duct.

Eqs. (8,11,12 and 13) have been used for evaluating the hourly useful energy and exergy and corresponding energy and exergy efficiencies and its hourly variation have been shown in Figs. 5 and 6, respectively. It is evident that there is variation of energy efficiency between 55% and 65%. The total energy varies from a minimum value of



Fig. 7. (a) Monthly total energy analysis for Srinagar. (b) Monthly total exergy analysis for Srinagar.



Fig. 8. Total energy (kWh) and exergy (kWh) per annum for different flow rates at Srinagar.

20 W/m<sup>2</sup> at 5 pm to a maximum value of  $340 \text{ W/m}^2$  at 12 pm for the month of January (Fig. 5a) where as it varies from a minimum value of  $100 \text{ W/m}^2$  at 5 pm to a maximum value of  $270 \text{ W/m}^2$  at 1 pm for the month of June (Fig. 5b). The variation in exergy efficiency as shown in Figs. 6 lies between 12% and 15% for the month of January and 13% and 14% for the month of June which is very close to the results obtained by Bosanac et al. [1]. The total exergy varies from a minimum value of  $5 \text{ W/m}^2$  at 5 pm to a maximum value of  $80 \text{ W/m}^2$  at 12 pm for the month of January (Fig. 6a) where as it varies from a minimum value of  $28 \text{ W/m}^2$  at 8 am and 5 pm to a maximum value of  $65 \text{ W/m}^2$  at 1 pm for the month of June (Fig. 6b). The variation in electrical output has been evaluated as shown in the numerator of Eq. (11).

The similar calculations were carried out for each case for each month and the total monthly useful energy and exergy were obtained and the results have been shown in Fig. 7. One can observe that the monthly total energy varies between 35 and 65 kWh and corresponding exergy varies between 8 and 15 kWh. This reduction is due to use of second law of thermodynamics in exergy analysis. The monthly energy and exergy are maximum (65 and 15 kWh, respectively) in the month of May and minimum (35 and 8 kWh, respectively) in the month of December; this is due to the more number of clear days available in the month of May as compared to the month of December (Table 4).

Effect of flow rate on yearly energy and exergy in the terms of kWh has been shown in Fig. 8. It shows that the energy and exergy increases with increase of flow rate due to faster use of thermal energy available with PV module as expected. However there is significant decrease in exergy due to more heat losses from the system during use of thermal energy.

## 4. Conclusions

On the basis of present analysis it is clear that there is an increase of about 2-3% exergy due to thermal energy in addition to its 12% electrical output from PV/T system, which makes an overall electrical efficiency of about 14–15% of PV/T system.

#### Acknowledgements

The authors are grateful to the Indian Meteorology Department (IMD), Pune, India for providing the hourly global and diffuse radiation and ambient temperature data for Srinagar for four years (1998–2001).

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