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Different Cases of Hybrid PV/T Air Collector: A Comparative Study

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Abstract: **The Thermal modelling of different cases of Hybrid PV/T air collector module i.e. Case A(Glass-Tedlar having duct below Tedlar),Case B(Glass-Glass having duct below PV module),Case C(Glass-Tedlar having duct of glass above PV module),Case D(Glass-Glass having duct of glass above PV module) is done. The various parameters like daily average Electrical efficiency ,hourly variation of Electrical efficiency, Electrical output, Thermal output,exergy gain is evaluated for the Jodhpur city and comparative analysis was done with different cases. The carbon Credit analysis of all the four cases was also found out and comparison is also done to find out the most Economical one.**

Keywords: **Solar radiation, Hybrid PV/T air collector, Electrical output, exergy gain**

1. INTRODUCTION

To solve seriously increasing environmental problem, renewable energy has been considered as a clean energy source. Solar energy is one of the most important sources of renewable energy. Generally, solar system can be classified into two categories: thermal systems which convert solar energy to thermal energy, and photovoltaic systems which convert solar energy to electrical energy. The use of conventional electrical energy can be avoided if combination of both types of thermal collector and photovoltaic collector is hybrid in one unit named hybrid collector or photovoltaic thermal collector (PV/T). In PV/T system applications the production of electricity is the main priority, therefore it is necessary to operate the PV modules at low temperature, the carrier of thermal energy associated with the PV module may be either air or water. Several theoretical and experimental studies of hybrid photovoltaic thermal systems are available in the literature. Coventry (2005)[2] has studied the performance of a concentrating PVT collector and concluded that an overall thermal and electrical efficiency of concentrating PV/T system are 58% and 11%, respectively. This gives a total efficiency of the system as 69%. Zondag et al. (2002)[1] have developed a model of a hybrid PVT air collector and performed experimental studies of such systems for varying sizes Chow et al. (2007)[4] found that forced convective cooling under a higher coolant flow velocity is better than the natural flow design. Nevertheless, the additional fan power consumption reduces the net electrical gain of the system.Tiwari et al. (2006)[3] have validated the theoretical and experimental results for PV module integrated with air duct for composite climate of India and concluded that an overall thermal efficiency of PVT system is significantly increased (18%) due to utilization of thermal energy from PV module. Tiwari and Sodha (2007)[17] presented a variety of results regarding the effect of design and operation parameters on the performance of air type PVT systems. Tonui (2008)[5] used free air convective cooling to remove heat from the back of the PV modules and to keep the electrical efficiency at an acceptable level. Free air convective cooling is simple and low cost method but a forced flow scheme provides a desirable cooling rate at all times. wVats and Tiwari (2012)[10] derived the analytical expression for room air temperature of building integrated semitransparent photovoltaic thermal (BISPVT) and building integrated opaque photovoltaic thermal (BIOPVT) systems each integrated to the roof of a room with and without air duct. The comparative study revealed that increase of air mass flow rate (0.85–10 kg/s) through duct increases the room air temperature from 9.4 to 15.2 ◦C for SPVT roof for a given climatic and design parameters. Bambrook and Sproul (2012)[11] illustrated the influence of fundamental parameter values on the thermal performance of the PV/T collector. Their experimental PVT air system demonstrated increasing thermal and electrical PV efficiencies with increasing air mass flow rate, with thermal efficiencies in the range of 28–55% and electrical PV efficiencies between 10.6% and 12.2% at midday.

2. SYSTEM DESCRIPTION

Here the PV module is supposed to fixed on a wooden structure for the support with an air duct of effective area of .61m^{2}The module is designed in such a way that we can change its inclination to maximise the solar radiation falling on it.In order to avoid the leakage of hot air ,proper sealing is necessarily provided.Different Temperature sensors are provided so they can measure the temperature at various points .There is arrangement of DC fan for continous removal of air from the duct. Solarimeter is used for measuring the hourly solar intensity and anemometer for measuring the air velocities at the inlet and outlet of the duct are used.

3. DIFFERENT CASE STUDIES

Different cases are taken for the climate of Jodhpur. In this paper, Four types of PV module are considered for analysis under different types of weather condition i.e Type a, Type b,Type c,Type d

- Case A: PV module with glass-tedlar with duct below PV module. In this case, solar radiation is absorbed by solar cell and EVA and it is then conducted to base of the tedlar for thermal heating of air flowing below tedlar .
- Case B: PV module with glass-glass with duct below module. In this case, solar radiation is absorbed by solar cell and black surface of insulating base and the flowing air is heated by convective heat from black surface as well as heat conducted from solar cell thorough glass cover below solar cell .
- Case C:Glass-Tedlar PV module with air flowing on the top of module in the duct of glass.In this case ,solar radiation is absorbed by solar cell and EVA and then it is conducted to tedlar and then it is also transfer to air flowing in the duct of glass above the module
- Case D: PV module with glass-glass with duct above module.In this case, solar radiation is absorbed by solar cell and black surface of insulating base and the flowing air is

4. THERMAL MODELLING

In order to write the energy balance equation, the following assumptions have been made:

A)The system is in quasi steady state condition (B) Ohmic losses in solar cell are negligible.(c)The heat transfer coefficient is constant.(D)The air flow through duct is uniform for the forced mode of operation for stream flow.

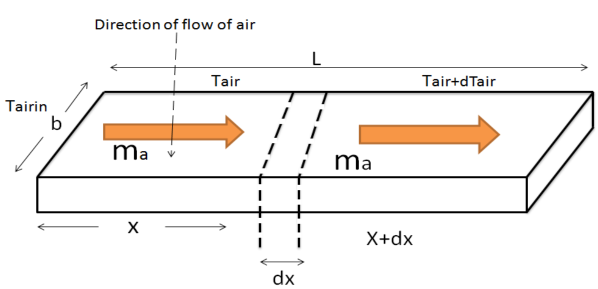


Fig1 An elemental length 'dx'showing flow pattern of air Following Tiwari et al.[12] and Joshi[13] , the energy balance equations for all cases in watts can be written.

5. RESULT AND DISCUSSION

After thermal modelling one can compare the different parameters for all the four cases. The variation of solar Intensity with respect to time through out the year for the weather condition of Jodhpur is taken.

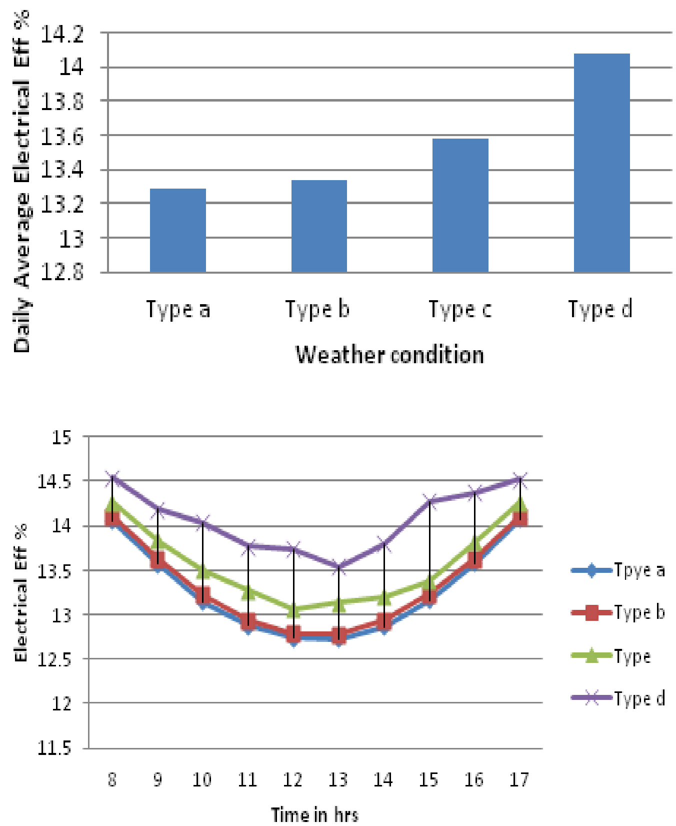
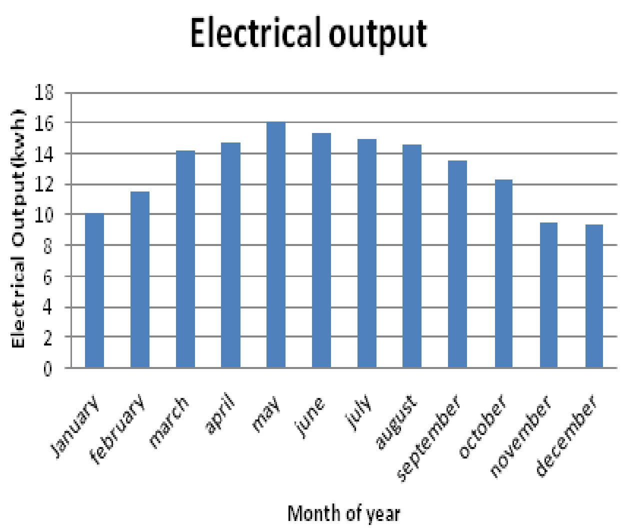


Fig2a Variation of daily average electrical effeciency with different weather condition in case A Fig2b Hourly variation of electrical efficiency for different weather condition in case A

In this paper,four cases are discussed i.e case A(Glass-Tedlar PV module having duct below Tedlar),case B(Glass-Glass PV module having duct below module ,case C(Glass-Tedlar PV module having duct above module) case D(Glass-Glass PV module having duct above module.Case C will give higher efficiency in comparison with case A and case B .This is due to the radiation falling on non-packing area of Glass-Glass module is transmitted through the glass cover while in Glass-tedlar all the radiation is absorbed by Tedlar and the heat is carried away by conduction so that the solar cell temperature is higher in case of case A and due to this effect ,there will result in decrease in efficiency of module. Daily average electrical efficiency of a,b,c and d type weather condition for case A is shown in fig2(a).It is seen from the graph that as solar Intensity decreases from a to d type weather condition ,the temperature of the solar cell decreases while efficiency increases.This result is also same for the case B ,case C &case D as shown in fig 3(a),4(a)&5(a).Hourly variation of electrical efficiency of Glass-tedlar PV module with duct below the tedlar is shown in fig2(b).Again it can be concluded from the graph that as solar intensity decreases from (a-d type)weather condition ,efficiency increases.The result for hourly variation of electrical efficiency for four different type of weather condition for case B, case C & cased is shown in fig3(b) ,4(b)& 5(b). This is in accordance with the result obtained by Dubey, sindhu & Tiwari (2009) [16].Fig2(c),3(c),4(c) &5(c)shows the monthly variation of Electrical output (kwh) for different cases i.e case A,case B & case C and case D.It is shown from the graph that month of May has got the highest value of electrical output for all the four cases.



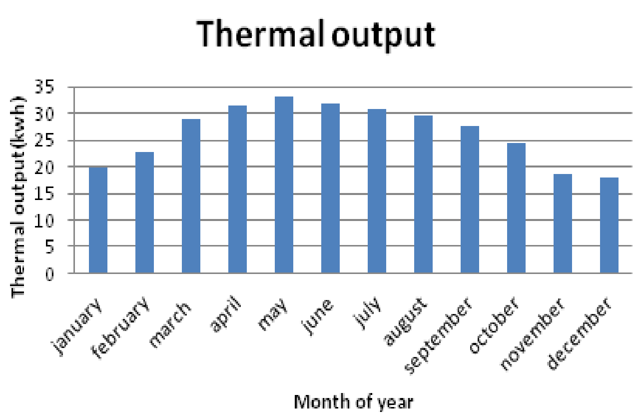
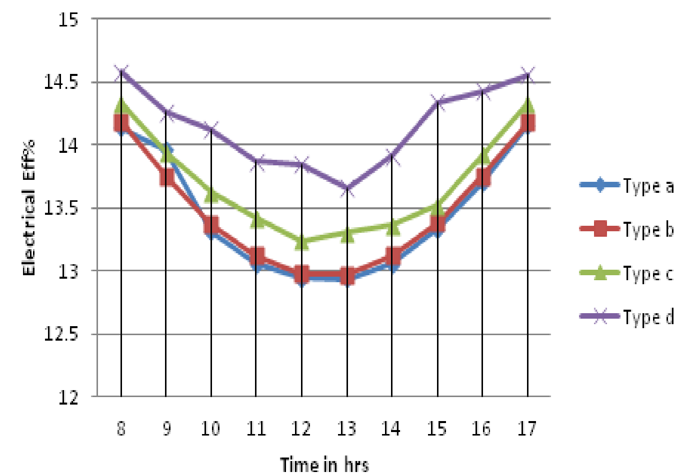


Fig2c monthly variation of Electrical output(kwh) in caseA
Fig2d monthly variation of Thermal output(kwh) in caseA

The monthly variation of Thermal output for all the four cases is shown in fig2(d),3(d) ,4(d) &5(d).It is again shown from the graph that case C has got the highest value of Thermal Output.By using a fan this thermal energy can be removed and used for various purpose like space heating,air heating,water heating,solar agricultural/crop drying etc.



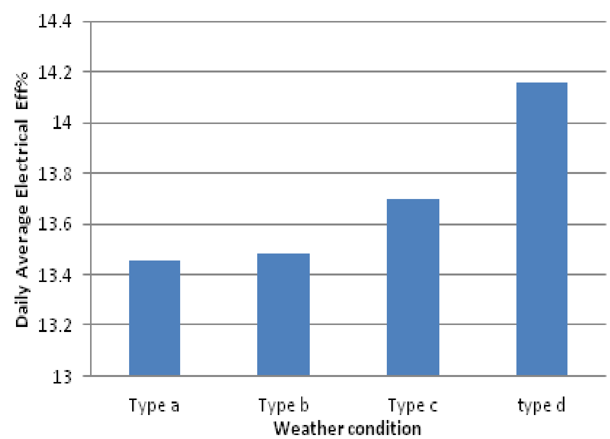
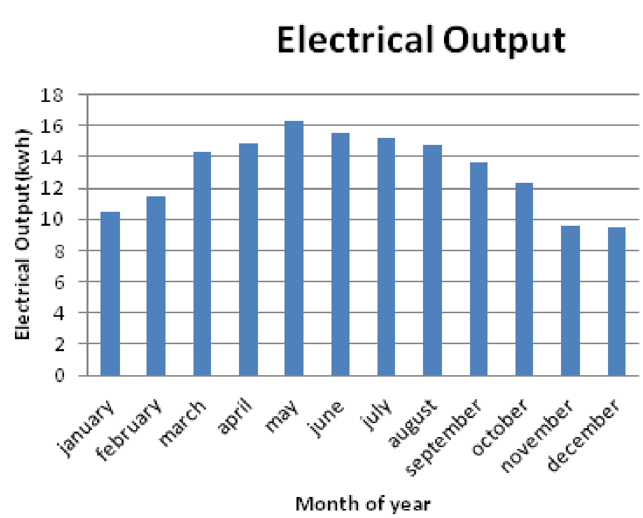
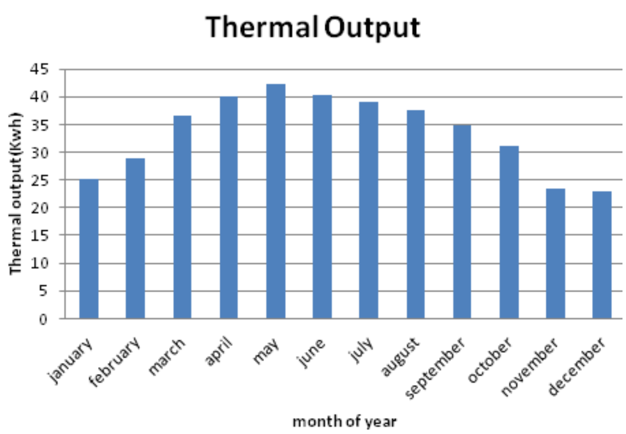


Fig3a variation of average electrical efficiency with different weather condition in case B Fig 3b Hourly variation of electrical efficiency for different weather condition in case B





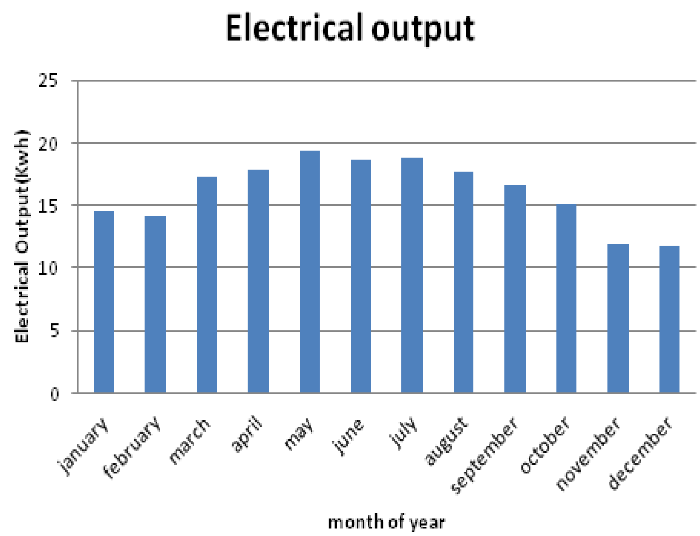
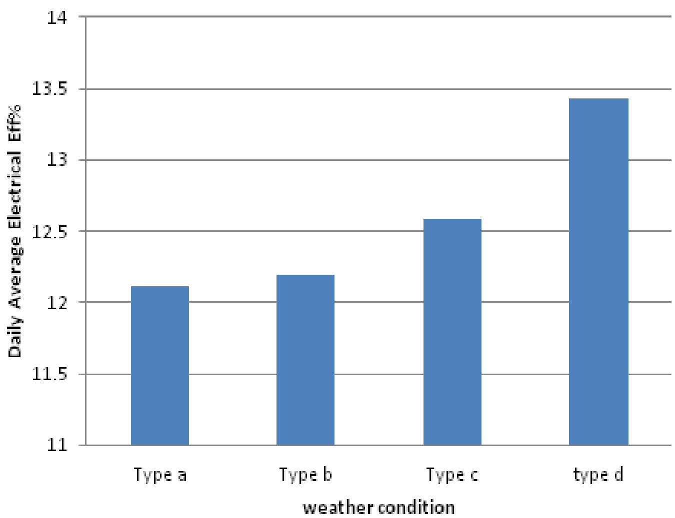


Fig3c monthlyvariation of Electrical output(kwh) in case B
Fig3d monthly variation of Thermal output(kwh) in case B



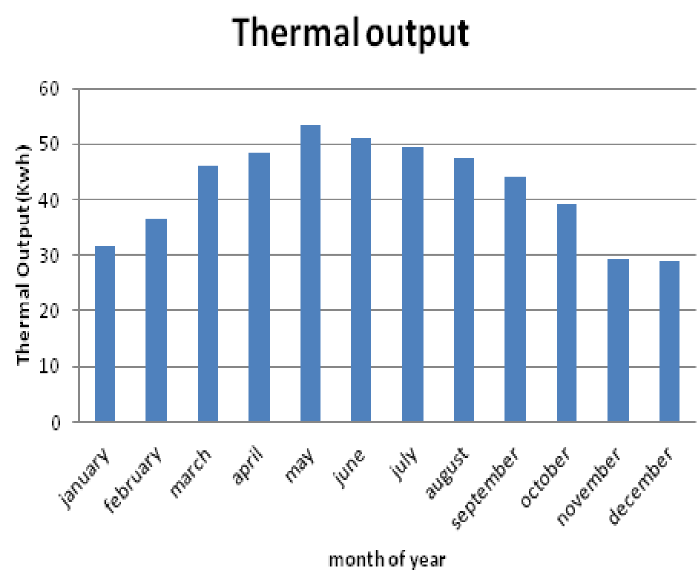
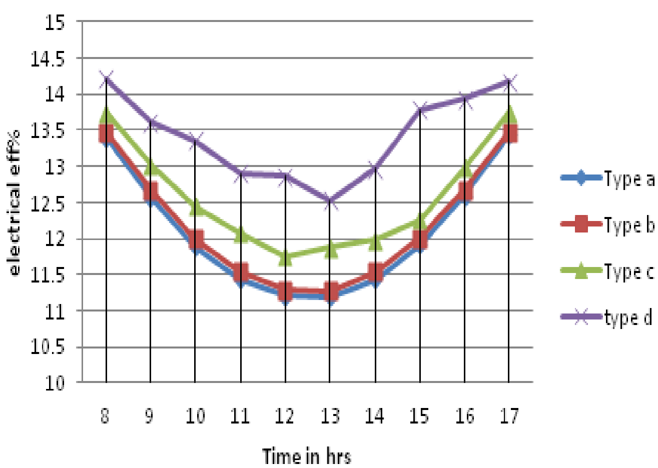


Fig4c monthly variation of Electrical output(kwh) in case C
Fig 4d monthly variation of Thermal output(kwh) in case C



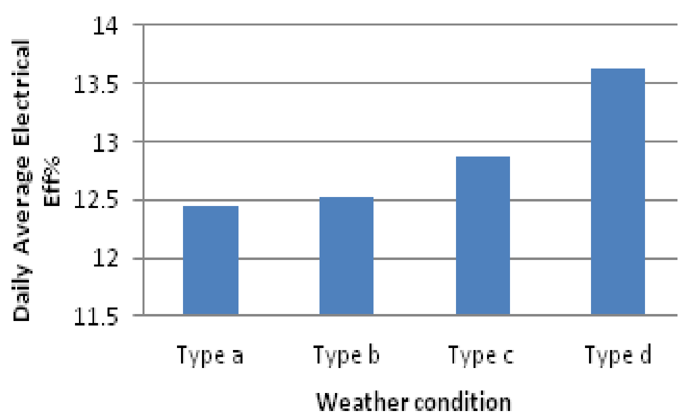


Fig 4 variation of average electrical for different weather condition in case C Fig 4b Hourly variation of electrical efficiency for with efficiency for different weather condition in case C

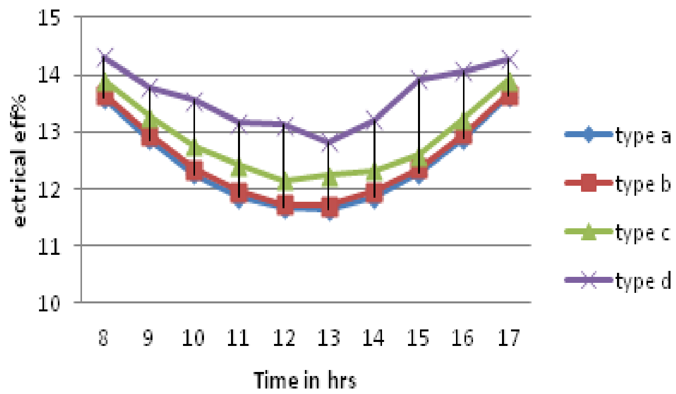
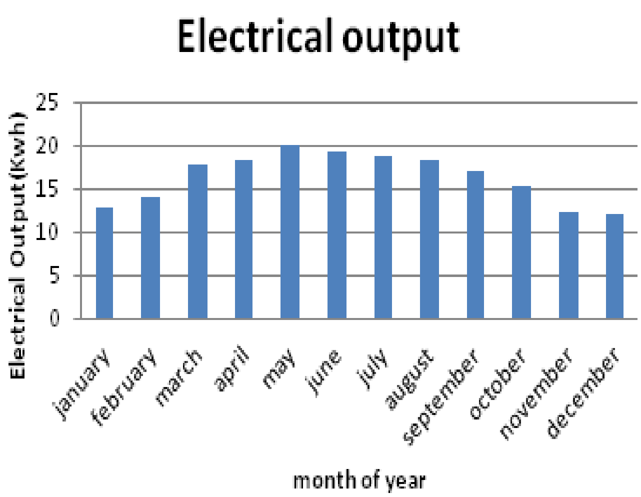


Fig 5a Variation of daily average electrical efficiency for different weather conditions in case D
Fig 5b Hourly variation of electrical efficiency for different weather condition in case D



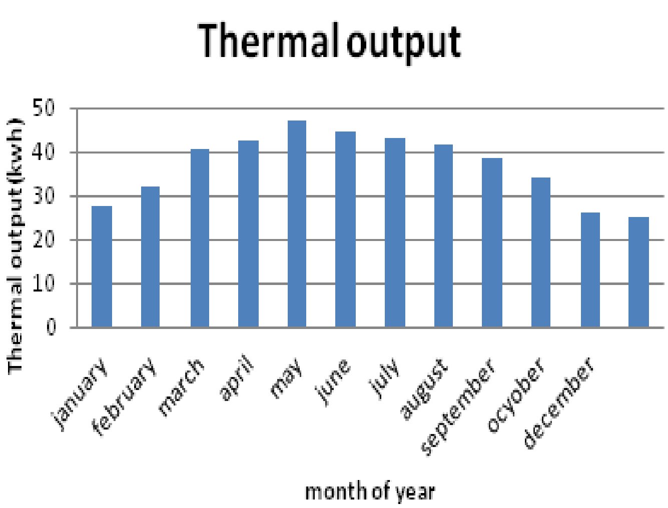


Figure 5c monthly variation of Electrical output(Kwh)in case D
Figure 5d monthly variation of Thermal output (Kwh) in case D

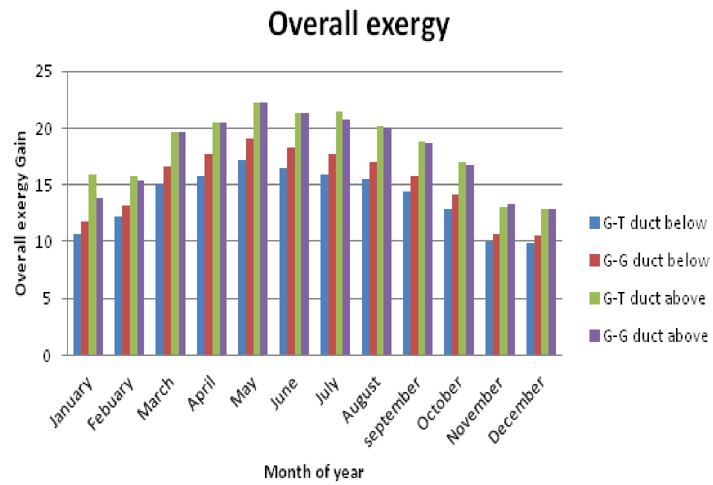


Fig6 Monthly variation of overall Exergy gain of Four cases

6. ENVIROECONOMIC ANALYSIS

The greenhouse gas (GHG) emission especially CO2, into the environment poses a great hazard to the society and therefore, demands an environmental assessment specifically in terms of economics The enviroeconomic analysis is based upon price of CO2 emission into the environment, which is the most powerful mechanism to promote the deployment of renewable energy technologies that does not emit carbon to the atmosphere.

Computation of environmental cost which is given $Z_{co2}=z_{co2}X\square_{co2}$

where ZCO2 is the enviroeconomic (environmental cost)parameter (CO2 mitigation price per annum) ($/annum) and zCO2 is the carbon price per tCO2 (21 $/tCO2). $\square_{co2}$ is CO2 mitigation per annum (tCO2/annum).In case A environmental cost is Rs 562,in case B (Rs618),in case C(Rs741),in case D(Rs.730)

7. CONCLUSION

This study has dealt with performance evaluation of hybrid photovoltaic thermal(PV/T) air collector system.The four types of photovoltaic(PV) module namely PV module glass-tedlar having duct below tedlar,PV module with glass-glass having duct below module,glass-Tedlar module having duct above module,glass-glass module having duct above are considered for comparison purpose. The monthly variation of thermal & electrical energy gain is shown in fig2c,2d,3c,,3d,4c &4d,5c,5d..It is to be noted that maximum thermal and electrical gain has been observed in the month of May and minimum in month of December because variation of gain depend upon the solar radiation and no. of clear days belong to that particular month. From the study following conclusion can be done;

- Glass-Tedlar PV module having duct above will have higher thermal efficiency in comparison with other type of module
- Glass-tedlar PV module having duct above module will have higher electrical output in comparison with two other type of module.
- The Average of daily average electrical efficiency is highest in case B.
- Exergy gain is highest in case C
- Highest Environmental cost is obtained from case C.

8. ACKNOWLEDGEMENT

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