Photovoltaic Thermal System And Their Various Aspects: A Review

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Abstract: Due to rapidly growing market demand for solar Thermal and photovoltaic Electricity generation, there are lot of ideas coming up with the aim for a wide range of application including agriculture, processing plant and buildings. In the building sector the size of building space is limited for the accommodation of solar devices but on the other hand cooling of solar device is also necessary otherwise it will burn out due to excessive increase in temperature. In order to overcome all these disadvantages, use of hybrid solar technology for multigenerational of active power and/or passive devices has been implemented. This Paper Present a review of the literature available during the last decade on the PV/Thermal collector. The paper is presented in a way so as to cover the comparison of different types of collector on the basis of their Electrical as well as Thermal parameters. The review cover the different types PV/Thermal collector system i.e. flat plate and concentrating type in which the working medium is either liquid or air, numerical models and Analysis, work done by using different tool i.e. simulation and qualitative performance on the basis of Thermal and Electrical output. From the Literature survey it can be concluded that PV/Thermal are very promising Devices and there is a wider scope to improve their performance on the basis of efficiency and cost, making them more competitive in the market.

Key words: PV/Thermal types, different module concept, performance analysis, Technique aiding heat transfer, Exergoeconomic analysis, Overall exergy, Overall thermal energy.

1 INTRODUCTION

Today there is a need for clean and renewable energy sources. Fossil fuels are non-renewable and require finite resource which are dwindling because of high cost and environmentally damaging retrieval technique, so there is a need for cheap and obtainable resource. A feasible and an efficient option is the solar energy. Due to its plentiful availability and derived directly from the sun, solar energy is a more practical form of energy. In 2010 in united state, renewable energy is only providing 8% of the total energy consumption. Then there is a question arises if renewable energy is so beneficial, why don't we consume it more? The answer to the above problem is that these renewable energy sources are limited, expensive and more difficult to retrieve.

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Thus due to these limitations the consumption of fossil fuels has grown to an exorbitant rate. Solar radiation totals about 3.8 million EJ per year and many other form of renewable energy are dependent upon it.PV/T is a hybrid system which can provide 300% more energy in the form of solar Electricity and solar heat as compare to conventional solar PV/T system.PV module captured the heat energy and ducted into building HVAC system to replace the heating load[1].The secondary advantage is to provide PV cooling by reducing the operating temperature of PV module, which in turn improve electrical performance. Excess heat build up behind PV panels is a major problem and for every 1^0C above 25^0C, the electrical output reduces by .4 to .5%.

TECHNOLOGY	WATT/M^2
PV Electrical output	100
Thermal output	200-300
Hybrid PV/T	300-400

The Hybrid PV/T technology also produces the additional benefits-

1. System addresses the majority of building's energy requirement, which is both heat and Electricity.
2. The hybrid PV/T will have higher life cycle cost savings when compare to convention PV system.
3. Due to displacement of gas or heating oil fuel, large reduction in greenhouse gas emission occurs.
4. Hedges against both Electricity and heating cost.
5. Allows for production of two type of solar energy from one Footprint.

The PV/T module consist of module in which PV module is combined with solar Thermal collector forming one Device that can convert solar radiation into heat and Electricity simultaneously.PV/T system generate more energy output at a lower production and Installation cost. At the National solar Test Facility in conjunction with the International Energy Agency Task35, performance of Solar Wall PV/T hybrid technology was established through Testing [1]. The result shows that when PV array is added with solar wall thermal component boost the total solar efficiency to over

50% compared with 10% to 15% Efficiency for PV module alone. The heat from PV panels, captured by solar wall perforated absorber, was found to be three times more than the Electrical Energy generated from PV module. The Test data also showed that Temperature gain from PV module is between 6 to 20^{0}C or well within the typical range for a commercial single-stage solar wall solar heating system.

2) Developments

The demand of solar heat and solar electricity are supplement to each other, and then there is a need of developing such device which can meet both the demands. There are many research carried out on PVT which result in integrating PV and thermal in one module[58].The main developments are.-

(2.1)Grid connected applications

- **(a)** With the aim of increasing efficiency, research on PVT started during mid 1970's with the focuses on PVT collectors. During the starting years care attention was on glazed collector both air and liquid type but later on focus changes to unglazed PVT collector with a heat pump.
- **(b)** Providing ventilation to PVT array for reducing temperature has lead to the idea that this heat could also be used.

(2.2)Autonomous system

- **(a)** Small air collector in which fan is driven by PV has been developed for ventilation of cottage.
- **(b)** Research also carried out on the aspect of thermal and Electrical output.

(2.3) here research on replacing concentrator PV by cheap reflector was done. It must also be kept in mind that Cooling is also necessary to reduce temperature.

3) PV/T COLLECTOR TYPES

By choosing the appropriate PV/T system, the thermal demand can be covered. Depending upon the type of module as well its design, type of heat-removal fluid (water/glycol or air), concentration of the incoming radiation, there are various forms of PV/T system-

- **(a)** Flat plate collector
- **(b)** PV/T concentrator collector
- **(c)** Working fluid(water/air)collector.

3.1 FLAT PLATE COLLECTOR-The flat plate collector looks like a flat plate thermal collector. There is a one PV panel which is attached on the top of metallic absorber plate .PV Panel contains the PV module, glass cover as well as well as the Absorption plate within the tubes.

3.2 PV/T CONCENTRATOR COLLECTOR

Combination of PV module with solar radiation concentration devices is the most efficient method to reduce the system cost by replacing the expensive cell with a cheaper solar radiation concentration system. Here a large PV area is replaced by a cheap mirror area, and this will also reduce the payback time. In comparison to normal one, concentrating photovoltaic has the higher efficiency, but this is possible only when PV module temperature is maintained as low as possible. Reflective and refractive optical devices are used in concentrating solar system and are characterized by their concentration ratio (CR).concentrating system with CR>2.5,must use a system to track the sun, while for system with CR <2.5,stationery devices are used. The Electrical output is affected by mainly two problems, one is the distribution of solar radiation on absorber surface (PV module) and other is the temperature rise of it. The uniform distribution of the concentrated solar radiation on PV surface and suitable cooling adds to an effective system operation and the achievement of high Electrical output.PV/T absorber can be combined with low, medium or high concentration devices.

3.3 FLUID PV/T COLLECTOR

Here conductive metal piping or plates are attached to the back of a PV module. A working fluid (glycol, mineral oil or water) is then piped through pipes [2].The heat is conducted through the metal and is absorbed by the working fluid. It is to presume that the operating temperature of the cell is at a higher temperature than a working fluid. In closed loop system, this heat is either exhausted or transferred at a heat exchanger. In open loop system this heat is used or exhausted before the fluid returns to PV cell.

3.4 AIR PV/T COLLECTOR

Air type PV/T collector is distinguished upon the manner in which the air is flowing. These are also differentiated upon the basis of either the air is flowing above the absorber or below the absorber or both sides of the absorber in single and in double pass. In general the air collector are mostly applied if there is a demand for hot air, space heat, dry agricultural products or to condition the indoor air(air cooling).using air as a heat transport medium compared to air, has significant advantages and disadvantages-

Advantages-

1. No freezing and no boiling of collector fluid.
2. No damage if leakage occurs.

Disadvantages—

1. Low heat capacity and low conductivity, the result is low heat transfer.
2. Low density due to which there is high volume transfer.
3. High heat losses through air leakage.

4 WORK DONE ON PHOTOVOLTAIC DURING THE PERIOD 2000-2013

HEGAZY [10]2000, investigated the thermal, electrical, hydraulic and overall performances of flat plate photovoltaic/thermal (PV/T). Four popular designs are considered with the air flowing either over the absorber (Model I) or under it (Model II) and on both sides of the absorber in a single pass (Model III) or in a double pass fashion (Model IV). The effects of air specific flow rate and the selectivity of the absorber plate and PV cells on the performances have been examined. It was found that under similar operational conditions, the Model I collector has the lowest performance, while the other models exhibit comparable thermal and electrical output gains. Nevertheless, the Model III collector demands the least fan power, followed by Models IV and II.

B. J. HUANG et al. [3]2001, demonstrate the idea of an IPVTS design. The test results show that the solar PV/T collector made from a corrugated polycarbonate panel can obtain a good thermal efficiency. The primary-energy saving efficiency of the present IPVTS exceeds 0.60. The characteristic daily efficiency η***** reaches 0.38 which is about 76% of the value for a conventional solar hot water heater using glazed collectors (η ***** 50.50). The performance of a PV/T collector can be improved if the heat-collecting plate, the PV cells and the glass cover are directly packed together to form a glazed collector. The manufacturing cost of the PV/T collector and the system cost of the IPVTS can also be reduced.

TRIPANAGNOSTOPOULOS et al. [11]2002, present test results on hybrid solar systems, consisting of photovoltaic modules and thermal collectors (hybrid PV/T systems). Hybrid PV/T experimental models based on commercial PV modules of typical size are described and outdoor test results of the systems are presented and discussed. The results showed that PV cooling can increase the electrical efficiency of PV modules, increasing the total efficiency of the systems. Improvement of the system performance can be achieved by the use of an additional glazing to increase thermal output. Pietruszko and Gradzki[31]2002, summarises 1 year of monitoring of a roof-mounted 1-kWp grid-connected system in Warsaw. The result shows that the annual system energy yield is about 830 kWh, and the performance ratio ranges from 0.6 to 0.8. The efficiency of the PV system is in the range of 4–5%. A computational thermal model for analyzing the annual performance of facade-integrated hybrid photovoltaic/thermal collector system for use in residential buildings of Hong Kong was presented by **Ji.J, CHOW T.T and He W [4]2003**. Simulation results showed that the annual average electrical efficiencies of the hybrid EPV and BPV modules are, respectively, 4.3% and 10.3%, the corresponding annual average thermal efficiencies to hot water are 47.6% and 43.2%, and the reductions of space heat gain in summer season through the collector wall are 52.9% and 59.1%. The overall thermal efficiencies are 58.9% and 70.3% respectively, which are much better than the conventional solar collector performance. W. Durisch et al. [5]2003,modify a small grid-connected thermo photovoltaic (TPV) system consisting of an ytterbia mantle emitter and silicon solar cells with a 16% efficiency (under solar irradiance at standard test conditions, STC). The most important modifications are: – (1) To prevent losses of convertible radiation in the water, and to protect the cells against the flue gases ,the infrared radiation-absorbing water filter between the emitter and silicon cells (to protect the cells against overheating) has been replaced by a suitable glass tube.(2) Cell cooling has been significantly improved, in order to reduce the cell temperature, and therefore increase the conversion efficiency. (3) The shape of the emitter has been changed from spherical to a quasi-cylindrical geometry, in order to obtain a more homogeneous irradiation of the cells. (4) The metallic burner-tube, on which the ytterbia emitter was fixed in the initial prototypes, has been replaced by a heat-resistant metallic rod, carrying ceramic discs as emitter holders. This has prevented the oxidation and clogging of the perforated burner tube. (5) Larger reflectors have been used to reduce losses of useful infrared radiation. (6) Smaller cells have been used, to reduce the electrical series-resistance losses. A system efficiency of 1.5% was attained by applying all these improvements to the basic 1.35 kW prototype. By using preheated air for combustion (at approximately 370 °C), 1.8% was achieved. Elham and Nather[46]2003, consider the feasibility of using PV systems for the pumping of ground water in comparison with using diesel units, taking into consideration the different parameters affecting the costs and the present value of both systems in “East Owienat” in Upper Egypt. He proved that PV-battery systems can be used efficiently for water pumping at East Owienat. The cost of the water unit pumped by PV systems is much less than that pumped using diesel systems, and the water cost is more sensitive to PV cells’ prices than ηtheir life-time periods. Hawlader et al.[47]2003,has designed, fabricated and tested a solar-assisted heat-pump dryer and water heater under meteorological conditions of Singapore.Result shows that the values of COP, obtained from the simulation and experiment are 7.0, and 5.0, respectively, whereas the solar fraction (SF) values of 0.65 and 0.61 are obtained from simulation and experiment, respectively. Jaber et al.[12]2003, evaluate the performance as well as predict the total energy-conversion efficiency and the incurred costs under various operating conditions of a photovoltaic (PV) gas-turbine hybrid system, with a compressed-air store. It was found that integrated PV and gas-turbine hybrid plant produces approximately 140% more power per unit of fuel consumed compared with corresponding conventional gas-turbine plants. Transfer and air flow in a composite-wall solar-collector system with a porous absorber by using the ‘unsteady’ numerical simulation was studied by **CHEN & LIU [16]2004**, and result shows that influences of the particle size and the porosity of the porous absorber on the air temperature should be taken into account for a better design of the passive solar-heating system. Badran and Hamdan [14]2004,compare theoretical and experimental study for under floor heating system using solar collectors and a similar system using solar ponds under the same local conditions and obtained that the solar collector system is 7% more efficient than the solar pond system. Economic analysis show that the Solar Collector System (SCS) will break even earlier than the Solar Pond System (SPS). Tang and Wu[17]2004, done a reasonable estimation of the optimal tilt angle of a fixed collector for maximizing its energy collection based on the monthly global and diffuse radiation on a horizontal surface and compare the optimal tilt angles of collectors obtained from expected monthly diffuse radiation and that from the actual monthly diffuse radiation . The result shows that this method gives a good estimation of the optimal tilt angle, except for places with a considerably lower clearness index. Kalogirou[13]2004, uses artificial neural-networks and genetic algorithms, to optimize a solar-energy system in order to maximize its economic benefits. He optimizes an industrial process heat-system employing flat-plate collectors.The result obtained increases life-cycle savings of 4.9 and 3.1% when subsidized and non-subsidized fuel prices are used respectively, as compared to solutions obtained by the traditional trial-and-error method and greatly reduces the time required by design engineers to find the optimum solution. Chow and Chan [33]2004, presented a numerical analysis of the solar irradiation received at the coastal region of South China. The analyses estimated the solar irradiation received on inclined surfaces at different orientations and slopes, and for different periods of the year. It was found that a solar collector facing the south-west direction could be most desirable for a wide range of tilt angles, and for maximizing the annual yield. The trends of variations towards other directions tilt angles, and shorter periods of the year were also explored. Yuehong Bi et al. [48]2004, studied theoretical and experimental performance for a solar-ground source heat-pump (SGSHP) system with a vertical double-spiral coil (VDSC) ground heat-exchanger (GHX). The heating mode of the SGSHP system is alternated between a solar energy-source heat-pump (SSHP) and a ground-source heat-pump (GSHP) using a low-grade energy utilization system built by them. The heat absorption rate per unit of ground surface area occupied by the GHX is shown to be 18 times greater than a single-pipe horizontal heat-exchanger. The coefficient of performance (COP) of the system with GHX is a 21% improvement over the system with the single-pipe horizontal heatexchanger.A.A.AlKaraghouli[6]2004, fabricate and tested Two solar-stills (single basin and double Decker) at the Campus of the University of Bahrain. Both stills have the same basin area. Several copper-constantan thermocouples were installed in both stills to measure the glass cover temperature, the chamber temperature, the water temperature and the ambient-air temperature. The hourly amount of extracted distilled water, the various temperatures and the insolation were monitored for a five-month period (February–June). Two types of measurements were performed; one with still-sides insulation and the other without. It was found that the monthly average amount of the total daily-distilled water production was highest in June for both types of stills. For the double-basin still, with sides insulated, the June production was 1760 ml per day (3.91 l/m^2/day), and in the non-sides insulation case the total daily amount was 1410 ml per day (3.13 l/m^2/day). For the single-basin still, the June daily production was 1280 ml per day (2.84 l/m^2/day) in the case of stills with sides insulation and 1105 ml (2.455 l/m^2/day) in the case of no-side insulation .Bezir et al. [36]2008, studied the amount of solar energy harvested by Two covers, which are collapsible has been developed .Computational modeling has been carried out for the determination of the performance of insulated and uninsulated solar ponds having different sizes with or without covers and reflectors. It was found that Reflectors increase the performance of the solar ponds by about 25%.

JOSHI et al.[24]2009, by evaluating the thermal performance of a hybrid photovoltaic thermal (PV/T) air collector system with glass-to-tedlar and glass-to-glass for composite climate of New Delhi, found that Back surface temperature is more in glass-to-glass PV/T air collector than in glass to tedlar PV/T air collector. Overall thermal efficiency of glass-to-glass PV/T air collector is more as compared to glass-to-tedlar PV/T air collector, overall thermal efficiency decreases with increase in length of the duct in both cases, Overall thermal efficiency increases with the increase in the velocity of duct air. Solanki et al. [22]2009, developed an indoor standard test procedure for thermal and electrical testing of PV/T collectors connected in series and found that the thermal and electrical efficiency of the solar heater is 42% and 8.4%, respectively. H. Zhai et al. [56]2009, proposed and investigate a small scale hybrid solar heating, chilling and power generation system, including parabolic trough solar collector with cavity receiver, a helical screw expander and silica gel–water adsorption chiller. A case study was carried out to evaluate an annual energy and exergy efficiency of the system under the climate of northwestern region of China. It is found that both the main energy and exergy loss take place at the parabolic trough collector, amount to 36.2% and 70.4%, respectively. Also found is that the studied system can have a higher solar energy conversion efficiency than the conventional solar thermal power generation system alone. The energy efficiency can be increased to 58.0% from 10.2%, and the exergy efficiency can be increased to 15.2% from 12.5%. The economical analysis reveals that the PP of the proposed system is about 18 years under present energy price conditions. Energy metrics (energy payback time, electricity production factor and life cycle conversion efficiency) of hybrid photovoltaic (PV) modules has been analyzed by Arvind Tiwari et. al[37]2009, and presented for the composite climate of New Delhi, India. For hybrid PV module, it was observed that the EPBT gets significantly reduced by taking into account the increase in annual energy availability of the thermal energy in addition to the electrical energy. The values of EPF and LCCE of hybrid PV module become higher as expected. Mercaldo et al.[38]2009,present analysis on architectural issues and technological developments of thin film silicon photovoltaic. Result shows that the ZnO material, with a low sheet resistance (<8 Ω/sq) and with an excellent transmittance (>82%) in the whole wavelength range of photovoltaic interest, has been obtained. "Micromorph" tandem devices, consisting of an amorphous silicon top cell and a microcrystalline silicon bottom cell, are fabricated by using the very high frequency plasma enhanced chemical vapor deposition technique. An initial efficiency of 11.1% (>10% stabilized) has been obtained. Shiv Kumar & Tiwari[23]2009, presents the life cycle cost analysis of the single slope passive and hybrid photovoltaic (PV/T) active solar stills, based on the annual performance at 0.05 m water depth. The result shows that the comparative cost of distilled water produced from passive solar still (Rs. 0.70/kg) is found to be less than hybrid (PV/T) active solar still (Rs. 1.93/kg) for 30 years life time of the systems. The payback periods of the passive and hybrid (PV/T) active solar still are estimated to be in the range of 1.1–6.2 years and 3.3–23.9 years, respectively, based on selling price of distilled water in the range of Rs. 10/kg to Rs. 2/kg. The energy payback time (EPBT) has been estimated as 2.9 and 4.7 years, respectively. Arvind Tiwari et al. [55]2009, obtains an analytical expression for the water temperature of an integrated photovoltaic thermal solar (IPVTS) water heater under constant flow rate hot water withdrawal. Further, an analysis has also been extended for hot water withdrawal at constant collection temperature. It was observed that the daily overall thermal efficiency of IPVTS system increases with increase constant flow rate and decrease with increase of constant collection temperature. The exergy analysis of IPVTS system has also been carried out. It was further noted that the overall exergy and thermal efficiency of an integrated photovoltaic thermal solar system (IPVTS) is maximum at the hot water withdrawal flow rate of 0.006 kg/s. The hourly net electrical power available from the system has also been evaluated. T.T. Chow et al. [57]2009, carried out a study of the appropriateness of glass cover on a thermosyphon-based water-heating PV/T system. The influences of six selected operating parameters were evaluated. From the first law point of view, a glazed PV/T system is found always suitable if we are to maximize the quantity of either the thermal or the overall energy output. From the exergy analysis point of view however, the increase of PV cell efficiency, packing factor, water mass to collector area ratio and wind velocity are found favorable to go for an unglazed system, whereas the increase of on-site solar radiation and ambient temperature are favorable for a glazed system.

VARUN AND SIDDHARTHA[51]2010, made an attempt to optimize the thermal performance of flat plate solar air heater by considering the different system and operating parameters to obtain maximum thermal performance. for a fixed value of number of plates (N = 1, 2 and 3) and fixed irradiance (I = 600, 800, 1000 and 1200) and varying Reynolds number ranging from 2000 to 20000, the optimized set of values of velocity (V), tilt angle (b), emissivity of plate (ep) and ambient temperature (ta) are obtained. Experimental results for flat plate solar air heater at V = 1, b = 0, N = 1 and I = 1000 are compared with the most close input parameters which are used in GA algorithm. The result shows that the experimental values are uniformly lesser within the reasonable limits than the obtained GA results.

CANER et al. [26]2011, constructed and examined experimentally two types of solar air collectors called as zigzagged absorber surface type and flat absorber surface type called Model I and Model II respectively. They estimate thermal performances of solar air collectors by designing an artificial neural network (ANN) model. He concluded that the artificial neural network (ANN) model using LM learning algorithm was successfully used to predict the complex nonlinear relationship between the thermal performance and input variables of two type solar air collectors. The comparisons between the predicted data and experimental data proved MLP model has a capability of recognizing the underlying relationship between input and output events. Also statistical error analysis proved reliability and accuracy of the MLP model. Li et al. [20]2011, characterized by Experiment for the electrical and thermal performance of a 2 m^2 Trough Concentrating Photovoltaic/Thermal (TCPV/T) system with an energy flux ratio 10.27 . The experimental results show that the electrical performance of the system with the GaAs cell array is better than that of crystal silicon solar cell arrays. But the thermal performances of the system using the single crystal silicon solar cell array and the polycrystalline silicon solar cell array are better. Another 10 m^2 TCPV/T system with an energy flux ratio of 20 using the GaAs cell array and a concentrating silicon cell array are also constructed and characterized. The experimental results indicate that the photoelectric efficiency of the GaAs cell array is 23.83%, and the instantaneous electrical efficiency and thermal efficiency of the system are 9.88% and 49.84% respectively. While the instantaneous electrical efficiency and thermal efficiency of the system using the low-cost concentrating silicon cell array are 7.51% and 42.4% respectively. On the basis of economic performance, analysis show the electricity generating cost of the TCPV/T system with the concentrating silicon cell array can catch up with flat-plate PV system, but besides electricity generation, the TCPV/T system supplies extra heat energy to users. Kang-Soo et al. [21]2011, study the Enhanced Performance of Solar cells With anti-reflection layer fabricated by nano-imprint lithography. The patterned solar cell was characterized using UV–vis spectrophotometer, atomic force microscope (AFM) and scanning electron microscope (SEM), and its total conversion efficiency was measured by solar simulator's. Result shows that, a solar cell with the moth-eye pattern as an anti-reflection layer showed lower reflectance and enhanced total conversion efficiency, compared to a solar cell without a moth-eye patterned layer. As series resistance increases, the voltage drop between the junction voltage and the terminal voltage becomes greater for the same current. The result is that the current-controlled portion of the I-V curve begins to sag toward the origin, producing a significant decrease in the terminal voltage V and a slight reduction in I_{SC}, the short-circuit current. Very high values of R_S will also produce a significant reduction in I_{SC} was verified by Ming Li et al. [25]2011. They demonstrate characteristics (I-V) of the solar cell arrays and the output performances of the TCPV/T system among the investigated four types of solar cell arrays, the triple junction GaAs cells possessed good performance characteristics and the polysilicon cells exhibited poor performance characteristics under concentrating conditions. The optimum concentration ratios for the single crystalline silicon cells and Super cells were 4.23 and 8.46 respectively, and the triple junction GaAs cells could work well at higher concentration ratio. When the series resistances R_s changed from 0 Ω to 1 Ω, the maximum power of the single crystalline silicon, the polycrystalline silicon, the Super cell and the GaAs cell arrays decreased by 67.78%, 74.93%, 77.30% and 58.07% respectively. When the cell temperature increased by 1 K, the short circuit current of the four types of solar cell arrays decreased by 0.11818 A, 0.05364 A, 0.01387 A and 0.00215 A respectively. The research results demonstrated that the output performance of the solar cell arrays with lower series resistance was better and the working temperature had a negative impact on the current under concentration. For the crystalline silicon solar cell arrays, when the solar direct radiation exceeded a certain value, the curves(I-V) almost became a straight line and the output performances decreased due to the high series resistance leading to the high power loss. For the triple junction GaAs solar cell array, its performance was always excellent. Kuznetsov et. al[39]2011,demonstrate that the application of transition metal-oxide nanorods to the surface of silicon solar panels can enhance the power output of the panels. Koussa et al. [40]2011, investigate the effect of using different sun tracking mechanisms on the flat plate photovoltaic system performances and the main parameters affecting the amount of their electrical energy output as well as those affecting their gains compared to the traditional fixed photovoltaic systems. It was found that for a completely clear day, the highest obtained gains are those related to the two-axis sun tracker systems, which decrease gradually from the inclined to the vertical rotating axis when the same optimum slope is applied and from the seasonal to the yearly optimum slope if the same rotating axis is considered. On the other hand, for the partially clear days, the gain amounts are mainly dependant on the clearness index and on the seasonal variation of day length values. For a completely cloudy day, the results show that all considered systems produced closely the same electrical energy and the horizontal position of the photovoltaic panel presented the best performance. Agrawal and Tiwari [41]2011, evaluate the theoretical performance of a glazed hybrid micro-channel solar cell thermal (MCSCT) tile. Experiment has been performed in indoor condition and it has been observed that there is good agreement between theoretical and experimental values with correlation coefficient and root mean square percentage deviation in range of 0.995–0.998 and 3.21–4.50 respectively. Effect of design parameters on different combination (series and parallel) of glazed hybrid MCSCT tile for Srinagar climatic condition, India has also been evaluated. The theoretical results of glazed hybrid micro-channel photovoltaic thermal (MCPVT) module for 75 Wp have been compared with the result of single channel photovoltaic thermal (SCPVT) module. The average value of electrical and thermal efficiency of glazed hybrid MCPVT module are 14.7% and 10.8% respectively which is significantly higher than SCPVT module. The overall annual exergy efficiency based on second law of thermodynamics has also been evaluated at different mass flow rate for glazed hybrid MCPVT module for Srinagar climatic condition. It has been observed that maximum overall exergy efficiency is 20.28% at 0.000108 kg/s mass flow rate.L.R. Bernardo et al. [42]2011, proposed and exemplified a complete methodology to characterize, simulate and evaluate concentrating photovoltaic/thermal hybrids in a particular case study from Sweden. The measurements show that the hybrid electrical efficiency is 6.4% while the optical efficiency is 0.45 and the U-value 1.9 W/m2 ^{o}C . These values are poor when compared with the parameters of standard PV modules and flat plate collectors. Also, the beam irradiation incident on a north–south axis tracking surface is 20–40% lower than the global irradiation incident on a fixed surface at optimal tilt. Rakesh Kumar and Rosen [43]2011,critically review photovoltaic–thermal solar collectors for air heating review of photovoltaic thermal technology and recent advances, particularly as applied to air heaters is also included. It was determined that the photovoltaic–thermal (PV/T) air heater is or may in the future be practicable for preheating air for many applications, including space heating and drying, and that integrated PV/T collectors deliver more useful energy per unit collector area than separate PV and thermal systems. Deepali Kamthania, Nayak and Tiwari[49]2011,presents the performance evaluation of a hybrid photovoltaic thermal (Semi transparent PVT) double pass facade for space heating. Numerical computations have been carried out for the composite climate of New Delhi, India. An analysis has been carried out to calculate annual energy and exergy gain for the hybrid photovoltaic thermal double pass facade. It has been observed that the annual thermal and electrical energy are 480.81 kWh and 469.87 kWh respectively. The yearly overall thermal energy generated by the system has been calculated as 1729.84 kWh. It is also observed that the room air temperature increases by 5–6 ◦C than the ambient air temperature for a typical winter day. Amir Nosrat and Pearce[8]2011, proposed PV-trigeneration system and found that an improvement in performance of over 50% available when a PV-CHP system also accounts for cooling.

TOMAS MATUSKA[9] 2012, discuss the two configurations of unglazed PV-T collectors (low-tech, high-tech) and their ability to eliminate overheating of BIPV module and found that Thermal output of unglazed BIPV-T collectors is up to 10 times higher than electricity. Electricity production could be up to 25% higher than BIPV (without cooling) for warm climate and up to 15% in moderate climate. Agrawal and Tiwari [29]2012, done the Exergoeconomic analysis of glazed hybrid photovoltaic thermal module air collector. In terms of energy saving analysis it has been concluded that the glazed hybrid photovoltaic thermal (PVT) module air collector offers a greater potential compared to PV module. The annual overall thermal energy and exergy gain are 1252.0 kWh and 289.5 kW h respectively. The annual net electrical energy savings by glazed hybrid PVT module air collector is 234.7 kW h.Mortezapour et al. [32]2012, by analysing the performance evaluation of a two-way hybrid photovoltaic/thermal (PV/T) solar collector found that the glass to glass PV/T solar collector gave higher outlet air temperature, cell temperature and thermal efficiency than the glass to tedlar PV/T solar collector. Maximum experimental electrical efficiency, thermal efficiency and overall thermal efficiency for the glass to tedlar PV module were found to be 10.35, 57.9 and 84.5%, respectively. Vats & Tiwari[27]2012, evaluate the energy and exergy performance of a building integrated semitransparent photovoltaic thermal (BISPVT) system integrated to the roof of a room. Comparison have been carried out on the basis of energy and exergy by considering six different photovoltaic (PV) modules. Observation shows that maximum annual electrical energy is 810 kW h for heterojunction comprised of a thin amorphous silicon (a-Si) PV cell on top of a crystalline silicon (c-Si) cell (also known as HIT) and the maximum annual thermal energy is 464 kW h for a-Si. It is also concluded that HIT PV module is suitable for producing electrical power whereas a-Si is suitable for space heating. However, an annual overall thermal energy (2497 kW h) and exergy (834 kW h) is maximum for HIT PV module. Rajoria,Agrawal and tiwari [28]2012, carried out overall thermal energy and exergy analysis for different configurations of hybrid photovoltaic thermal (PVT) array. A one dimensional transient model for hybrid PVT array has been developed using basic heat transfer equations. On the basis of this transient model, an attempt has been made to select an appropriate hybrid PVT array for different climatic conditions (Bangalore, Jodhpur, New Delhi, and Srinagar) of India. On the basis of high grade energy (i.e. overall exergy gain), case-III has been selected as the most appropriate configuration because overall exergy for case-III is 12.9% higher than case-II. The overall thermal energy and exergy gain for Bangalore is 4.54 _ 104 kW h and 2.07 _ 104 kW h respectively which is highest in comparison to the other cities. Rakhi Sharma and Tiwari[44]2012, investigate the performance assessment of a solar photovoltaic (PV) array system based on electrical energy output and power conversion efficiency.Performance indices for entire PV array and its individual conversion efficiency of entire PV array and its component subarrays1 and 2 were 6.24%, 9.5% and 3.9% respectively. Şenpinar and Cebeci[45]2012, compares the performance of two PV modules, one fixed and the other fitted with a two-axis tracking system which enables the PV collector to move and be controlled to follow the Sun's radiation. A computer unit was employed to monitor the solar radiation exposure of both systems and to control the movement of the solar tracking PVmodule.Throughout the day, the results obtained from the fixed and tracked systems were collected on a DAQ card installed on an online computer. Overall, it was found that the daily output power of the tracking module was 13–15% higher than the fixed module. The PVT air collectors, either glazed or unglazed, provide simple and economical solution to PV cooling. The air can be heated to different temperature levels through forced or natural flow. Forced circulation is more effective than natural circulation owing to better thermal convective and conductive behaviour, but the fan power consumption reduces the net electricity output. Their use is mostly to meet the demands on industrial hot air, indoor space heating, and/or agricultural dehydration**.**

AGRAWAL AND TIWARI [30]2013,done the comparative analysis of different type of photovoltaic thermal (PVT) air collector namely: (i) unglazed hybrid PVT tiles, (ii) glazed hybrid PVT tiles and (iii) conventional hybrid PVT air collectors for the composite climate of Srinagar (India) in terms of overall thermal energy and exergy gain, exergy efficiency and carbon credit earned by different type of hybrid PVT air collectors. It has been observed that overall annual thermal energy and exergy gain of unglazed hybrid PVT tiles air collector is higher by 27% and 29.3% respectively as compared to glazed hybrid PVT tiles air collector and by 61% and 59.8% respectively as compared to conventional hybrid PVT air collector. It has also been observed that overall annual exergy efficiency of unglazed and glazed hybrid PVT tiles air collector is higher by 9.6% and 53.8% respectively as compared to conventional hybrid PVT air collector. On the basis of comparative study, it has been concluded that CO2 emission reduction per annum on the basis of overall thermal energy gain of unglazed and glazed hybrid PVT tiles air collector is higher by 62.3% and 27.7% respectively as compared to conventional hybrid PVT air collector and on the basis of overall exergy gain it is 59.7% and 22.7%.

CONCLUSION: A review of the available literature on PV over the last decade was presented. The following conclusion have been reached-Various researchers showed their work done on the possibility of generating Electricity and heat Energy from PV/T with either water or air flow. Air PV/T collectors are less efficient than water.This paper also covers the thorough review on latest module aspect of the various technique to improve the overall performance of PV/T system. The thermal performance of a coverless PV/T collector is reduced especially at high temperature duet to heat loss from top.Electrical performance of coverless PV/T collectors is better.There exist no definite rules for PV/T collector and/or system use.The choice of technique depends upon the geographical location and its actual application.At location where level of radiation and ambient temperature is low,space heating is required through out the years so PV/T can be useful and cost effective.However,based on the overall view of the research done till date,it is concluded that there are still a lot of work to be done in design aspect before PV/T system can be successfully implemented and integrated into domestic and commercial application.PV/T system can supply buildings with 100% renewable electricity and heat by using the optimization design technique in comparison with separate PV and solar thermal system.since PV/T system has a much shorter economic payback period then PV counterpart,PV/T as a renewable energy technology in comparisons to PV is expected to become competitive with conventional energy sources on the top.

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