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Title

Design and Construction of a Hybrid Solar Photovoltaic / thermal collector (PV/T)

Before the jury composed of:

CHENNOUF Nasreddine	Pr	President	UKM Ouargla.
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Dedication

I dedicate this work to who taught me charity and hard work to the person that I proudly carry his name…my father "dine Mouhammed"

To my first school and my paradise my dear…mother may she rest in peace

To the person who gave me support and was there for me…

My second mother and my support in life… my dear sister the doctor " Amina"

To the one who stood by me and support me…my dear sister the professor "Fatima"

Thank you for everything you have given me

To my dear sisters… Khadija, messouda, dadi, ahlame, saliha.

To my brothers… Messoud, Boumama, Bakar.

I am also pleased to pay my own tribute to Dr. Moukhtar Lati for his efforts, advice and knowledge throughout this research.

To all the professors who influenced me to learn.

I dedicate my work to…Abd Razzak, Ahmed, Abd Lkader, and Hamoud

To my dear nephews and nices..Roumaisa, Loujain, Amira, Ritaj, Abd Raouf, Loai, Zaki, nunu,issra,amani,anes and razan.

To all my friends, the loving and caring…Mouhammed, Amin, Chourouk, Mordia.

To all members of Dine family.

Dedication of the student Dine Dounia

Dedication

I dedicate this work to who taught me charity and hard work to the person that I proudly carry his name…my father "Saouti Salah "

To my first school and my paradise my dear…mother

May Allah bless their hearts and keep you both in my life

To the person who gave me support and was there for me

Rafik Bouriche

To my brothers Rami, Siradje Edine

To my grandmother and grandfather may they rest in peace

I am also pleased to pay my own tribute to Dr. Moukhtar Lati for his efforts, advice and knowledge throughout this research.

To all the professors who influenced me to learn.

I dedicate my work to…Roufia, Siham, Ali, Afafe, and little Mouhemed

To all my friends, the loving and caring…Salssabil, Hadjer, Nour El-Hana, Dounia, Hakima, Marwa.

To all members of Saouti and Bareche families.

Dedication of the student Saouti and Bareche families.

SUMMARY

Figures list

General Introduction

Solar energy is commonly collected as heat and electricity through thermal and photovoltaic (PV) technologies, respectively. (Saeed Abdul-Ganiyu 1 and al, 2020)

A photovoltaic (PV) is a semi-conductor device that converts sunlight into electricity. PV panels are clean sources of energy portable and do not produce noise. (Kazem; 2019)

A calorific energy is generated during the photovoltaic conversion of the solar module, which increases the temperature of the cell and will cause a fall in its electric output. This phenomenon is, on one hand, due to the partial un absorptive solar radiation, which constituted the origin of the cells heating, and on the other hand, due to the Joule effect caused by the passage of the photo-electrical current generated in the external circuit. This heating, harmful for the photovoltaic cell output, involved many research efforts to limit its effects by evacuating this heat. There was also the idea to exploit this phenomenon by the combination of the photovoltaic module with a thermal system to form the photovoltaic thermal (PV/T) hybrid collector, which will generate, at the same time, electricity and heat. (Touafek and al)

In the recent years, the PV/T technology has received a large attention all over the world. In this work, the design of a new type of PV/T collector is described through its experimental study. This novel collector constitutes a new technical approach to maximize the total output of conversion with lower cost compared to the traditional collectors.

This PV/T collector has been experimented with a solar dryer to ensure the possibility of its operation of electrical fan, which ensure the forced convection of solar dryer.

The paper contains four chapter; the first chapter talks about the bibliographic study, some base nation about thermal, photovoltaic and Hybrid PV/T technologies, collectors, types and working principles.

Chapter two speaks about previous studies where Hybrid PV/T was included alongside with the results.

The step by step construction is mentioned in chapter three also the equipment and materials used.

The last chapter in this paper is chapter four where we discussed the results of our study, comment on each result separately.

The purpose from our study is to design and construct a Hybrid solar photovoltaic/thermal collector PV/T. The main focus is to find a solution for the decreasing of efficiency in PV panel relying on a cooling system within the collector itself.

CHAPTER I: Bibliographic study

I.1. Energy:

Global energy consumption in the last half century has rapidly increased and is expected to continue to grow over the next 50 years, however, with significant differences. The past increase was stimulated by relatively “cheap” fossil fuels and increased rates of industrialization in North America, Europe, and Japan; yet while energy consumption in these countries continues to increase, additional factors make the picture for the next 50 years more complex. These additional factors include China’s and India’s rapid increase in energy use as they represent about a third of the world’s population; the expected depletion of oil resources in the near future; and, the effect of human activities on global climate change. On the positive side, the renewable energy (RE) technologies of wind, biofuels, solar thermal, and photovoltaic (PV) are finally showing maturity and the ultimate promise of cost competitiveness. (Energy Efficiency and Renewable Energy Handbook)

Figure 1 shows different energy sources and the ways we utilize them. We see that usually the chemical energy stored in fossil fuels is converted to usable forms of energy via heat by burning, with an efficiency of about 90%. Using heat engines, thermal energy can be converted into mechanical energy. Heat engines have a conversion efficiency of up to 60%. Their efficiency is ultimately limited by the Carnot efficiency limit that we will discuss in Chapter 10. The vast majority of the current cars and trucks work on this principle. Mechanical energy can be converted into electricity using electric generators with an efficiency of 90% or even higher. Most of the world’s electricity is generated using turbo generators that are connected to a steam turbine, where coal is the major energy source. Along all the process steps of making electricity out of fossil fuels, at least 50% of the initial available chemical energy is lost in the various conversion steps. **(Solar energy)**

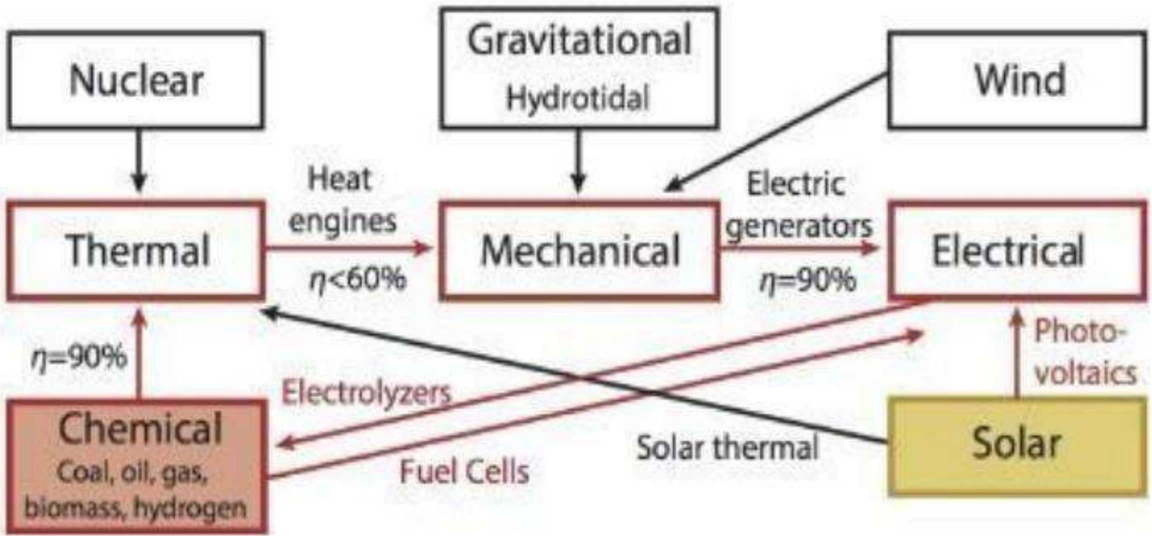


Figure (I.1) The different energy carriers and how we utilize them (Solar energy)

I.2. Solar energy

I.2.1. Definition

Solar energy is a radiation from the sun capable of producing heat, causing chemical reactions, or generating electricity. The total amount of solar energy incident on earth is vastly in excess of the world's current and anticipated energy requirements.

If suitably harnessed, this highly diffused source has the potential to satisfy all future energy needs.

The potential for solar energy is enormous , since about 200,000 times the world's total daily electric generating capacity is received by earth every day in the form of solar energy The Sun is an extremely powerful energy source, and sunlight is by far the largest source of energy received by earth, but its intensity at Earth's surface is actually quite low. This is essentially because of the enormous radial spreading of radiation from the distant Sun. A relatively minor additional loss is due to Earth's atmosphere and Cloud, which absorb or scatter as much as 54 percent of the incoming sunlight. The sunlight that reaches the ground consists of nearly 50 percent visible light, 45 percent infrared radiation, and smaller amounts of ultraviolet and other forms of electromagnetic.

(Paul Beattie MacCready, 2021)

I.2.2. Types of solar energy

I.2.2.a THERMAL:

Solar thermal technologies absorb the heat of the sun and transfer it to useful applications, such as heating buildings or water.

Solar thermal energy has the potential to meet the complete heating and cooling demand in the residential sector and to contribute significantly to the energy supply of the commercial and industrial sector. (Gerhard Faninger)

Solar thermal collectors transform solar radiation into heat and transfer that heat to a medium (water, solar fluid, or air). (N. El Bassam, 2021)

Figure (I.2) Thermal panels (www.isover-technical-insulation.com)

I.2.2.b PHOTOVOLTAIC:

Photovoltaic (often shortened as PV) gets its name from the process of converting light (photons) to electricity (voltage), which is called the *photovoltaic effect*. This phenomenon was first exploited in 1954 by scientists at Bell Laboratories who created a working solar cell made from silicon that generated an electric current when exposed to sunlight. Solar cells were soon being used to power space satellites and smaller items such as calculators and watches. Today, electricity from solar cells has become cost competitive in many regions and photovoltaic systems are being deployed at large scales to help power the electric grid. Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaic include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenite/sulfide. Photovoltaic solar panel is the most commonly used solar technology to generate electricity energy. The contribution of solar photovoltaic (PV′s) in generation of electric power is continually increasing. PV cells are commonly modeled as circuits. Finding appropriate circuit model parameters of PV cells is crucial for performance evaluation, control, efficiency computations and maximum power point tracking of solar PV systems (Renewable and Sustainable Energy Reviews 2016)

Figure (I.3) Photovoltaic panels (Gero Rueter, 2021)

I.3. Solar collectors

A solar collector is a device that collects and/or concentrates solar radiation from the Sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use. These collectors are generally mounted on the roof and must be very sturdy as they are exposed to a variety of different weather conditions. (Solar_collector)

The use of these solar collectors provides an alternative for traditional domestic water heating using a water heater, potentially reducing energy costs over time. As well as in domestic settings, a large number of these collectors can be combined in an array and used to generate electricity in solar thermal power plants. https://energyeducation.ca/encyclopedia/Solar_collector

I.3.1 Thermal Collectors

A solar thermal system utilizes solar energy to convert it into heat (thermal) energy by means of a circulating fluid. A solar thermal system essentially consists of a solar collector. The solar collector absorbs solar energy as heat and then transfers it to a heat transporting fluid, which delivers this heat either to a thermal storage tank or heat exchanger to be utilized in the subsequent stages of the system. (Tripathi and al, 2018)

I.3.1.a Thermal collector component

- **Glass cover:** has the function of isolating the solar collector from external environmental conditions and allowing solar radiation to pass through.
- **Absorber:** is the element that intercepts solar radiation inside the collector and is responsible for transforming solar energy into thermal energy.
- **Heat insulation:** it reduces the heat losses from the inside of the collector (specifically from the absorber) to the outside. It is made of synthetic foam sheets, located in the sides and back of the solar panel.
- **Back plate:** serves to house the rest of the components of the thermal collector. (Oriol Planas, 2018)

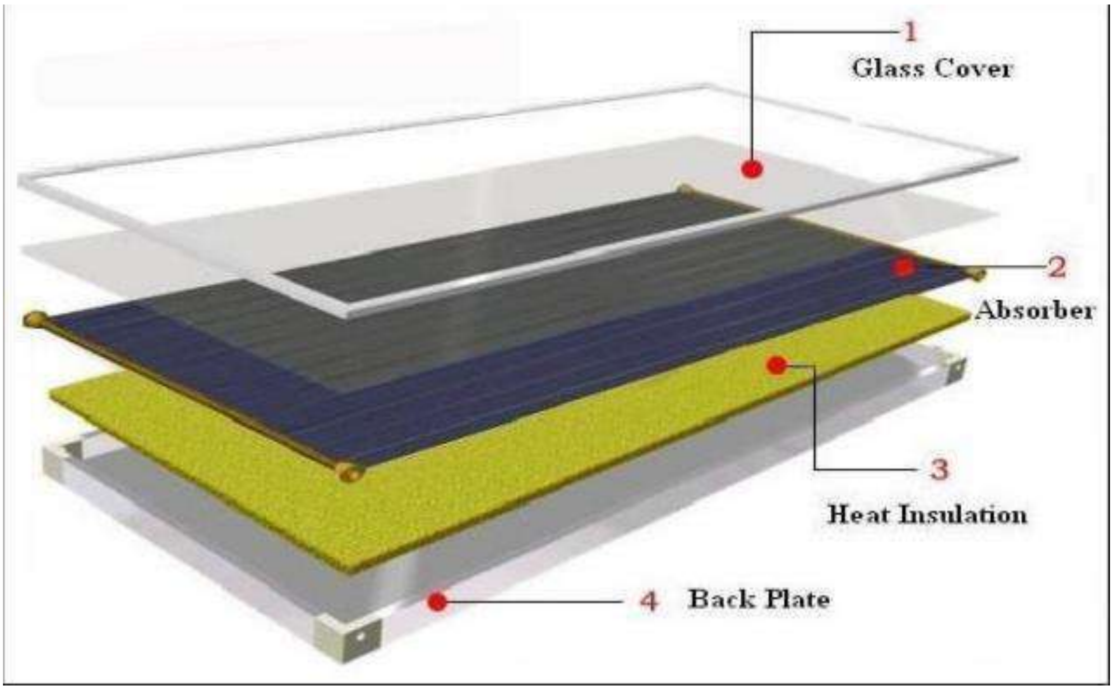


Figure (I.4) The components of thermal collector (leaai.us)

I.3.1.b The working principle of thermal collectors

The working principle is very simple. Basically, solar radiation impacts on the absorber heating it up. Since the absorber is treated with special paints only a very small solar radiation portion is reflected back to the environment. The produced heat is then transferred to the fluid. (F.Reda, 2017)

I.3.1.c Types of thermal collectors

Solar collectors can be classified depending on their geometric configuration or on the temperature obtained by the working fluid after gaining heat. According to their geometric configuration they can be flat solar collectors and concentrating solar collectors. (Alexander Alarcon and all 2013)

- **Flat solar collectors** are used primarily for space heating in the home. Flat-plate solar collectors are durable weatherproof boxes that contain a dark absorber plate located under a transparent cover. They can be used for heating both air and water.

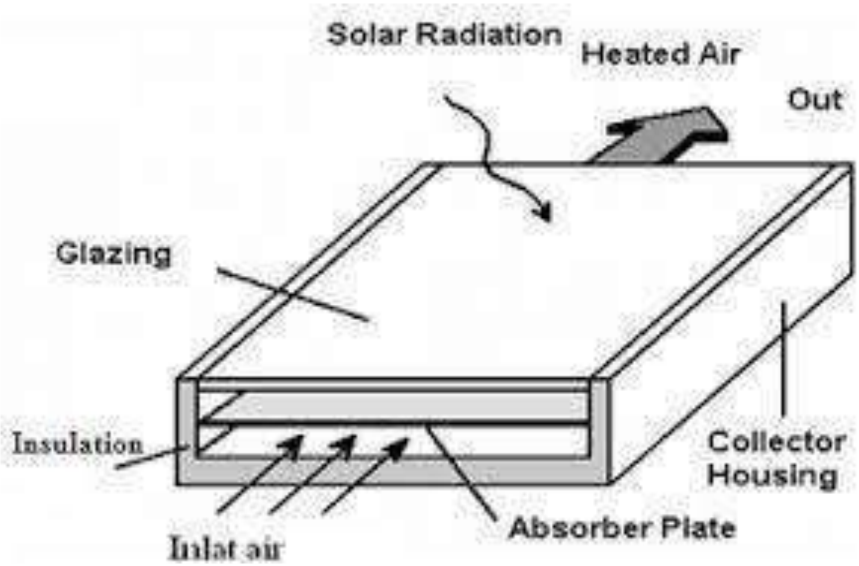


Figure (I.5) Air collector (Semantic scholar)

- **Concentrating collectors:** a concentrating collector utilizes a reflective parabolic-shaped surface to reflect and concentrate the sun's energy to a focal point or focal line where the absorber located. To work effectively, the reflectors must track the sun. These collectors can achieve very high temperature because the diffuse solar resource is concentrated in small area. (Tiwari G.N, 2017)

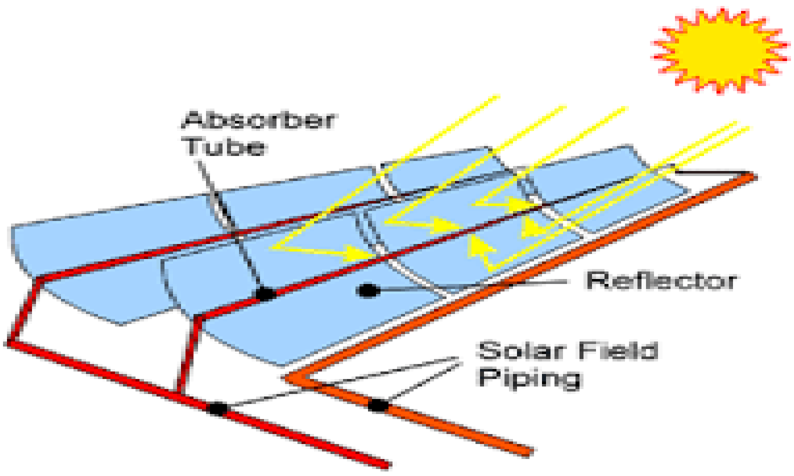


Figure (I.6) Concentrated collector (David Preprint, 2011)

- **Evacuated tube collectors:** they are constructed of a number of glass tubes. Each tube is made annealed glass and has an absorber plate within the tube, because tube is natural configuration of an evacuated collector. (Zanis Jesko, 2016)

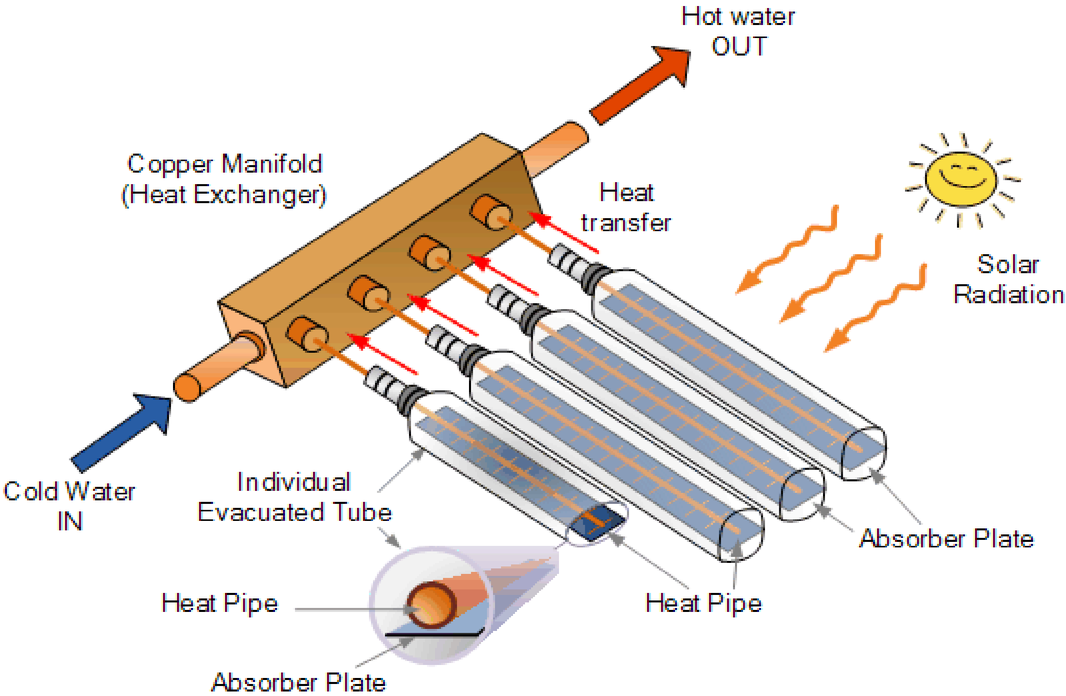


Figure (I.7) Tube collector (Krthi Keyan 2019)

I.3.1.d Thermal collector usage

For the solar air collector, there have been many studies on the thermal performance and the influencing factor of collectors, as well as the heating effect on the room thermal environment. Nowadays, building integrated solar thermal air collectors are frequently used in order to save the space, such as collectors integrated with the roof, the exterior wall the slab the interior wall and the other interior thermal mass. The integration of exterior wall and roof is often to supply the heated air directly into the room, the heat storage of the exterior wall and the roof is rarely exploited. Anatomy of a solar collector: Developments in Materials, Components and Efficiency Improvements in Solar Thermal Collector Systems

Figure (I.8) Roof installation of air heaters (solarheateurope.eu)

The thermal collectors used for solar water heating, which comprise thermo syphon, integrated collector storage, direct and indirect systems and air systems, space heating and cooling, which comprise, space heating and service hot water, air and water systems and heat pumps, refrigeration, industrial process heat, which comprise air and water systems and steam generation systems, desalination, thermal power systems, which comprise the parabolic trough, power tower and dish systems, solar furnaces, and chemistry applications. As can be seen solar energy systems can be used for a wide range of applications and provide significant benefits, therefore, they should be used whenever possible. Thermal collectors and applications 03

Figure (I.9) Water heater (energy.gov)

I.3.2. The photovoltaic panel

Photovoltaic (PV) panels are used to produce electricity directly from sunlight. PV panels consist of a number of individual cells connected together to produce electricity of a desired voltage. Since the maximum voltage from individual cells is less than 1 V, multiple cells are connected together in series on a PV panel. (J.F. Manwell)

I.3.2.a Photovoltaic panel component

These are solar cells made of semiconductor materials that have intermediate physical properties between conductors and insulators. The main components of a solar cell are:

- **Frame:** used to protect the constituents generated, it facilitates transport and installation.
- **Glass:** is a tempered glass with a low iron oxide content to ensure good transmission.
- **EVA:** Ethylene-vinyl acetate is a transparent resin, made of chains of copolymers of ethylene and vinyl acetate, it has great adhesive properties, good optical transmission, a very low rate of water absorption and also good electrical resistivity.
- **The solar cell:** is the basis of the PV module, it is formed with one or more semiconductor materials (homo-junction or heterojunction) with a doping.
- **Tedlar:** It is used behind the module; it is made of a fluorinated polymer called polyvinyl fluorinated (PVF) or a plastic called (PET).

(DOUES djamel and al, 2021)

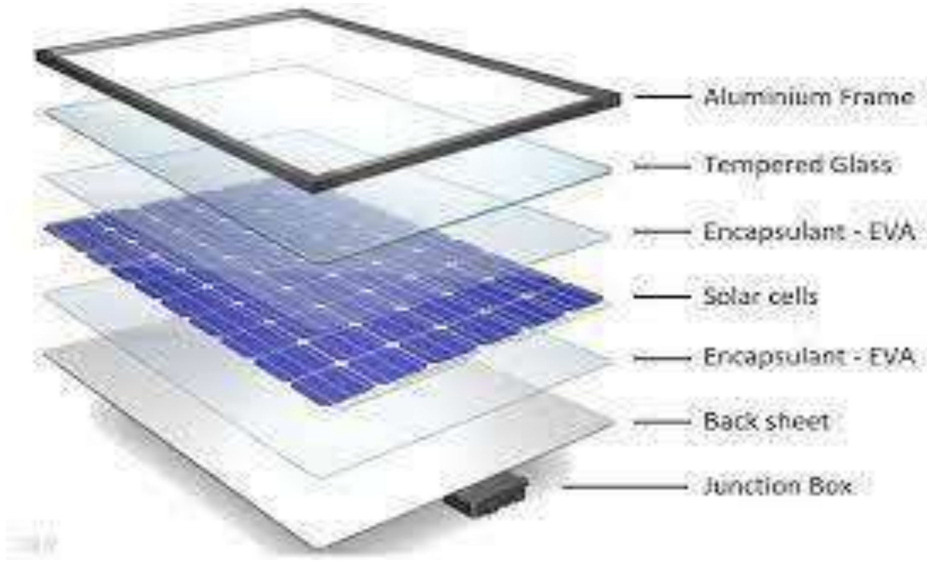


Figure (I.10) An example of photovoltaic panel construction (DOUES djamel, 2021)

I.3.2.b The working principles of the PV collector

Solar cells convert the energy in sunlight to electrical energy. Solar cells contain a material such as silicon that absorbs light energy. The energy knocks electrons loose so they can flow freely and produce a difference in electric potential energy, or voltage.
The flow of electrons or negative charge creates electric current. Solar cells have positive and negative contacts, like the terminals in a Battery. If the contacts are connected with a conductive wire, current flows from the negative to positive contact. The figure bellow show how the photovoltaic cell works. (SANTOSH DAS, 2022)

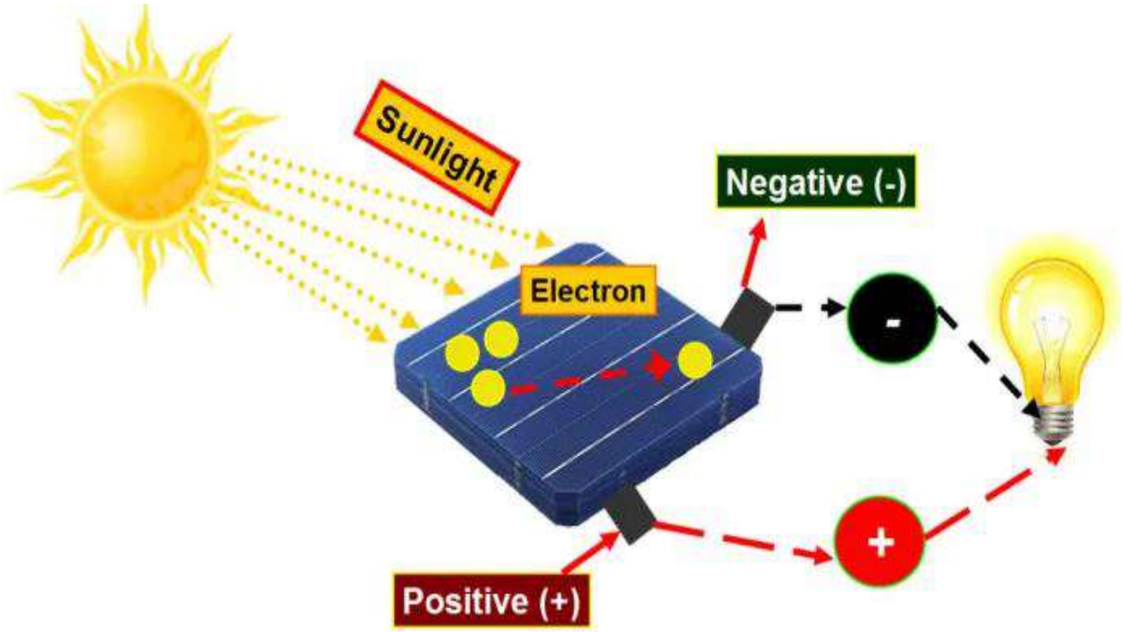


Figure (I.11) The working principles of PV cell (SANTOSH DAS, 2022)

I.3.2.c Types of photovoltaic collectors

These are the traditional types of solar panels:

- **Monocrystalline Solar Panels (Mono-SI)**

This type of solar panels (made of monocrystalline silicon) is the purest one. You can easily recognize them from the uniform dark look and the rounded edges.

- **The advantaged:** high power output; occupy less space; has a long lifetime; less effected by the high temperature.
- **The disadvantaged:** the most expensive type of photovoltaic collectors.

- **Polycrystalline Solar Panels (Poly-SI)**

You can quickly distinguish these panels because this type of solar panels has squares, its angles are not cut, and it has a blue, speckled look. They are made by melting raw silicon, which is a faster and cheaper process than that used for monocrystalline panels.

This one offers a shorter lifespan since they are affected by hot temperatures to a greater degree. However, the differences between mono- and polycrystalline types of solar panels are not so significant and the choice will strongly depend on your specific situation. The first option offers slightly higher space efficiency at a slightly higher price but power outputs is basically the same. (Askari Mohammad Bagher and al, 2015)

Figure (I.12) The difference between the monocrystalline and polycrystalline cells (Askari Mohammad Bagher and al, 2015)

I.4 Hybrid photovoltaic/thermal collectors (PV/T)

Systems that harness solar energy could be classified into two groups. First: systems that convert solar energy to thermal energy and systems that convert solar energy to electricity. The first group can further be classified into two: Systems that convert solar energy to thermal energy for heating purposes and systems that convert solar energy to thermal energy for electricity generation purposes. With the introduction of a third, hybrid type technology, a third group can be added to this figure, which is the Photovoltaic/thermal technology. Photovoltaic/thermal collectors combine the two technologies by offering thermal energy and electricity simultaneously from a single solar collector. Detailed classification can be observed at Figure (I.13) (Mustafa Kaya; 2013)
It is a combination of photovoltaic and solar thermal components integrated in a single system that is capable of generating electricity and heat simultaneously. (Slimani mouhemed al amine, 2017)

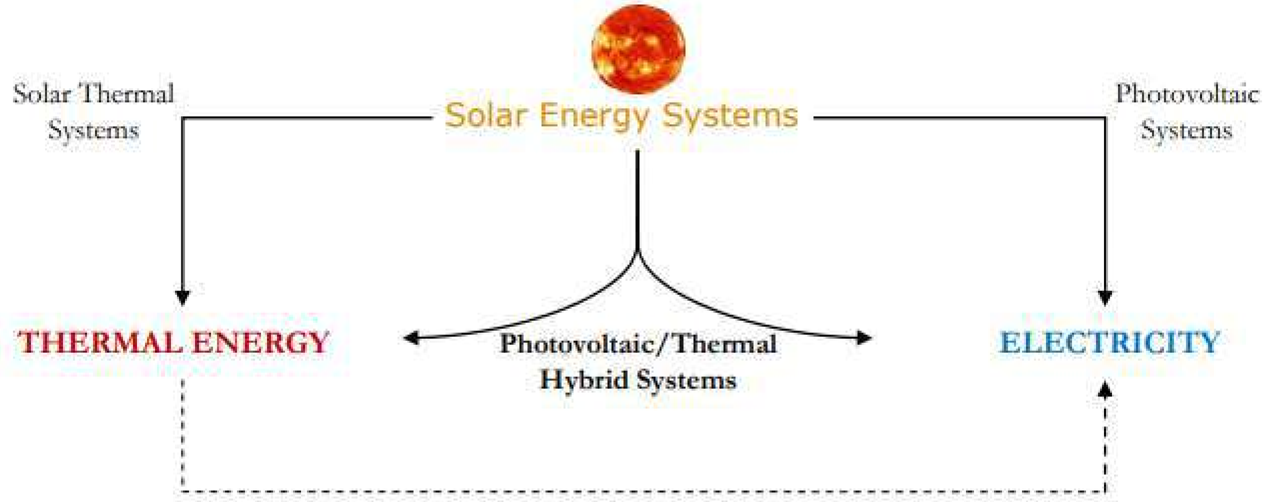


Figure (I.13) Hybrid photovoltaic/thermal systems (Mustafa Kaya, 2013)

I.4.1 Principle and operation of hybrid solar panels (PV/T)

The photovoltaic thermal hybrid system (PV/T) combining with thermal electricity provides both electricity and usable heat which can enhance total efficiency of the system. (Lougzhou Zhang and all)

I.4.2 The different types of hybrid solar systems

I.4.2.a Hybrid air solar collectors

These systems are able to generate heat produced under the panels and even electricity thanks to the ventilation, located on their rear face. These panels allow heat recovered by the thermal collectors to be diffused, which is very convenient in winter to reduce heating needs.

- **Photovoltaic solar panels (exposed to the sun):** it produces electricity like conventional photovoltaic panels.
- **Solar thermal panels (back side):** the back side has a ventilation device to recover and then diffuse hot air in a home or other. (DOUES djamel and al, 2021)

I.4.2.b Hybrid Water Solar Collector

Work like the air solar collectors except that they use the circulation of water or antifreeze water rather than that of air. This type can produce electricity and hot water. It is characterized by:

- **An efficient cooling system:** photovoltaic collectors are equipped with a water heat exchanger. Water can both cool the panel to maximize its electricity production and produce hot water.

- **Increased efficiency:** the cooling of the panel ensures a better performance compared to a conventional solution. (DOUES djamel and al, 2021)

I.4.2.c The uses of the hybrid PV/T collector

The use of these hybrid collectors is generally included in three main areas:

- **The field of housing**, in particular for heating applications (domestic water heating), air conditioning and lighting of houses.
- **Industrial field**, particular the use of heat for example to operate turbines (using hybrid concentrators), and to supply industrial equipment with the heat of electricity.
- **The field of agribusiness** for the drying of foodstuffs or for supplying electrical energy to landlocked agricultural areas. (Slimani mouhemed al amine, 2017)

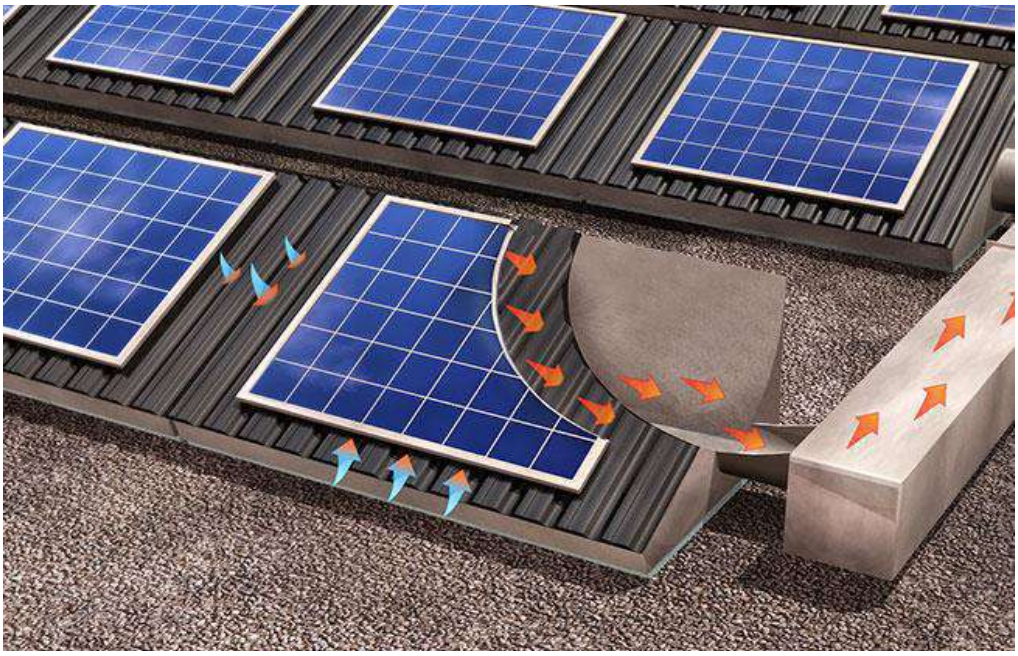


Figure (I.14) PV/T solar wall (solarwall.com)

I.5 Dryers

I.5.1. Solar dryers

Solar drying is one of the processes that have found application in Algeria, because of the important quantities of solar irradiations that can be exploited in this country.

Nevertheless, the experience of Algeria in solar drying is recent and limited to drying of fruits, vegetables, medicinal and aromatic herbs. The effectuated review has given an idea about the existing functional dryers in this country with presentation of their different design aspects and in some cases the mathematical modeling for well describing and predicting their behaviours. The solar dryers were classified into two classes according to their operation mode and without taking into account if the dryers are using auxiliary sources of energy. The two classes are: passive dryers and active dryers. On the other hand, each class was divided into subclasses representing the type. We have found the direct and indirect types for the passive dryers, but only indirect types for the active dryers. Mixed types were not developed. The solar dryers were developed and tested in two different climatic regions which are the north of the country and the Sahara. In the most studied cases, one or multiple auxiliary sources of energy were used in order to increase the performances of the dryer or to decrease drying time. Consequently, we register the utilization of pebbles as a heat storage system, resistances as electrical heater, gas-ring and photovoltaic cells in order to give independency against the use of the traditional electrical energy. In the case of the active dryers, adding fans and temperature and flow controllers has permitted the control of the drying conditions. Depending on the dryers, the dried quantities vary from 200 g to 36 kg. (Elsevier, 2011)

The objective of a dryer is to supply the product with more heat than is available under ambient conditions, thereby increasing sufficiently the vapor pressure of the moisture held within the crop and decreasing significantly the relative humidity of the drying air and thereby increasing its moisture carrying capacity and ensuring sufficiently low equilibrium moisture content. (Werner Weiss and al)

I.5.2 Function mode and component of solar dryers

The solar dryer consists of a box made up of easily available and cheap material like cement, galvanized iron, brick, and plywood. The top surface of the dryer is covered by transparent single and double-layered sheets. The inside surface is colored black to absorb the incoming solar radiation. Since the box is insulated, the inside temperature of the box is raised. The air is ventilated through the small holes at the top of the box. As the inside air gets warm, it rises by the natural circulation process and removes the moisture from the fruits, vegetables, and the crops placed in trays inside the box. To fill the vacuum, fresh air comes in by a forced draught process and the process continues, as shown in Figure bellow. (Muhammad Kamran, 2021)

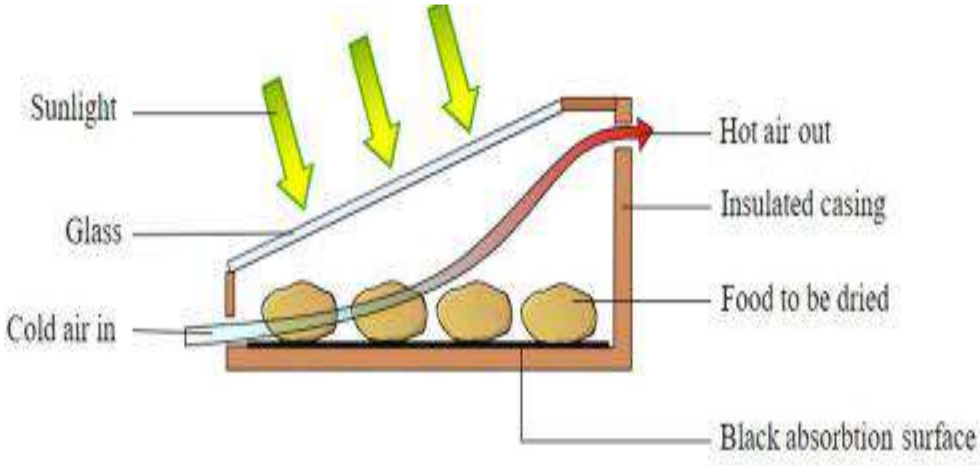


Figure (I.15) Solar dryer (Muhammad Kamran, 2021)

I.5.3 Types of solar dryers

Solar dryers are classified as follows:

- **Integrated (Direct) Solar Dryers:** In this type, the solar energy collection and drying takes place in a single unit. Some of the examples for this category include step type dryers, cabinet dryers, rack dryers, tunnel dryers, greenhouse dryers, and multi-rack dryers.
- **Distributed (Indirect) Solar Dryers:** In this type, the solar energy collection and drying takes place in two different units namely, a flat plate air-heater and a drying chamber. The flat plate heater can be placed on the roof of a building or on the ground or the place where the Sun's intensity is high. Air is heated in the flat plate heater and with the help of a blower; the heated air gets circulated in the drying chamber.
- **Mixed Mode dryer:** In this type, the solar energy collection takes place at both the flat plate air heater as well as a drying chamber and the drying takes place only at the drying chamber. The outer part of the dryer will also get solar energy; this helps to remove the moisture quickly. (Balaji MK, 2019)

Active Dryers: Active solar drying systems are designed incorporating external means, like fans or pumps, for moving the solar energy in the form of heated air from the collector area to the drying beds. Thus all active solar dryer are, by their application, forced convection dryer. A typical active solar dryer depends on solar-energy only for the heat source, while for air circulation uses motorized fans or ventilator. These dryers find major applications in large-scale commercial drying operations in combination with conventional fossil-fuel to have a better control over drying by consolidating the effect of fluctuations of the solar insolation on the drying air temperature.(C.L. Hii and al)

Passive Dryers: In a passive solar dryer, air is heated and circulated naturally by buoyancy force or as a result of wind pressure or in combination of both. Normal and reverse absorber cabinet dryer and greenhouse dryer operates in passive mode. Passive drying of crops is still in common practice in many Mediterranean, tropical and subtropical regions especially in Africa and Asia or in small agricultural communities. (Hughes and al, 2011)

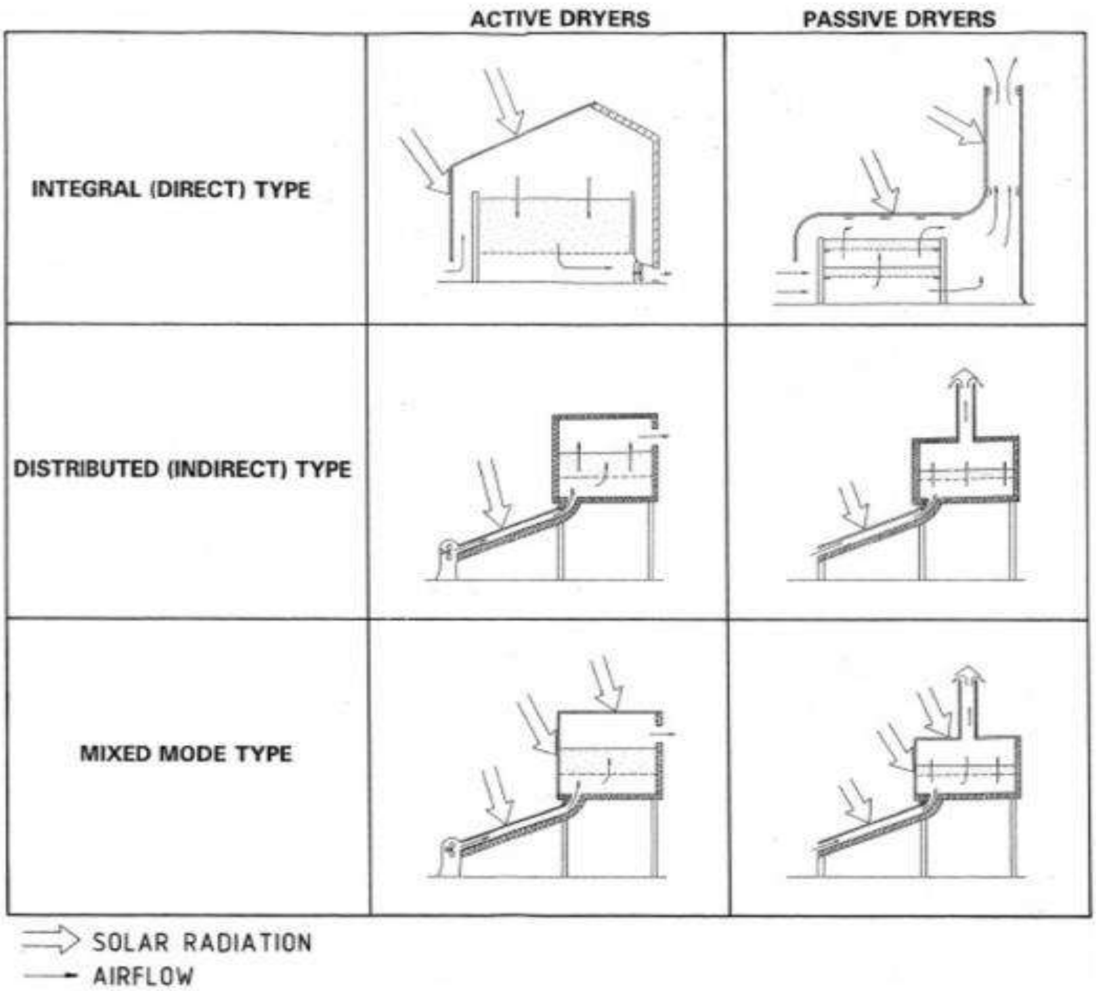


Figure (I.16) Classification of solar dryers (Werner Weiss and al)

CHAPTER II: Previous studies of Hybrid PV/T

II.1 Tiwari and al

A hybrid solar dryer of the greenhouse type in mixed mode, integrated with a number of solar collectors.

Solar collectors partially covered with photovoltaic/thermal solar collectors (Figure 17), has been proposed by Tiwari and all for drying. Different performance parameters are evaluated under the climatic conditions of New Delhi, India. Thermal modeling has been performed for the drying system and analytical expressions for different parameters such as product temperature, greenhouse temperature, collector outlet air temperature and cell temperature have been cell temperature were developed. In addition, the effect of the mass flow rate and of the variation on thermal energy, electrical energy, equivalent thermal energy, energy efficiency and

Equivalent thermal energy, thermal energy yield and overall thermal yield have been evaluated. It found that with the variation of the number of air collectors from 1 to 5, the equivalent thermal energy equivalent thermal energy, equivalent thermal efficiency and equivalent energy efficiency vary from 3.24 to 10.57 kWh / day, 61.56-42.22% and 28.96-19.11% respectively. (S.Tiwari, 2017)

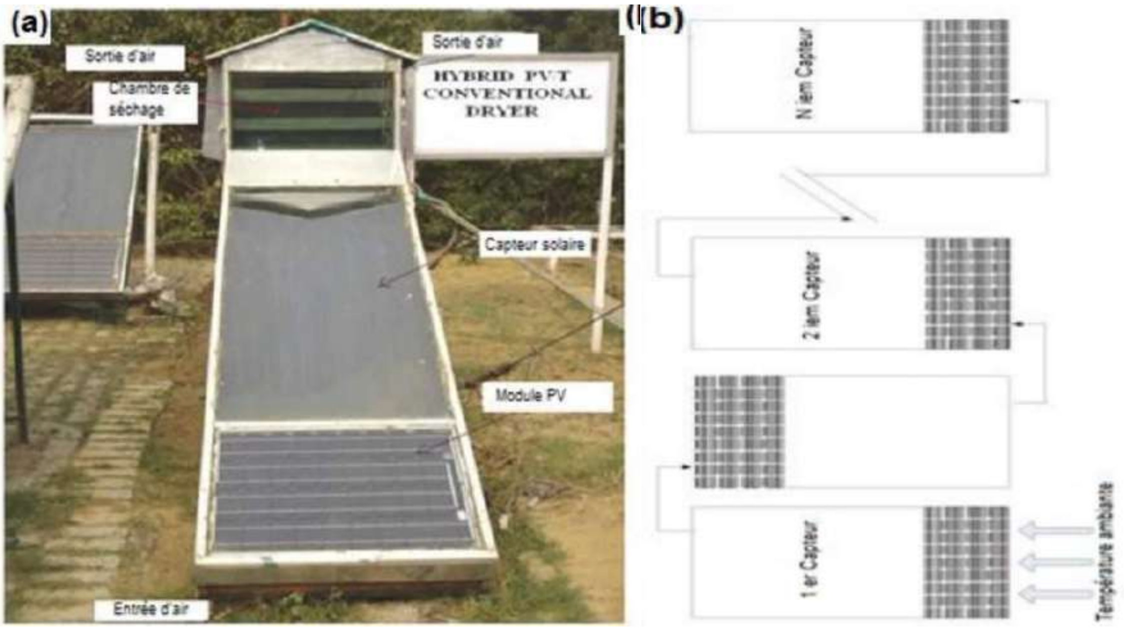


Figure (II.1): mixed greenhouse dryer integrated with pv/t air collector

(b) series of solar air collectors partially covered with pv/t collectors (S.Tiwari, 2017)

II.2 Higazy and al

Compared the thermal and electrical performance of four hybrid air-cooled PV/T solar collectors differentiated by the mechanical cooling mode of the PV modules: above the absorber (prototype I), below (prototype II), on both sides (prototype III), and by dual air circulations (prototype IV). The four prototypes are schematically shown in figure I.37. Each of these collectors is glazed with a length of 9 m, and a width of 1 m. The PV array is composed of 20 modules each consisting of 36 crystalline silicon PV cells connected in series. It covers 62.8% of the absorber surface which is 9 m2. The nominal electrical voltage at the terminals of a PV module is 16.5 V, i.e. a nominal power of 50 Wp. The stationary model realized for each of these components is unidirectional.

HEGAZY points out that the performance of an air-cooled PV/T hybrid solar collector depends on the maximum air outlet temperature, the thermal and electrical efficiencies, and the net electrical energy available after subtracting the energy required operating the fan and other devices powered by the PV module. The simulation performed for a sunny day showed that increasing the ventilation mass flow rate improves the thermal efficiency. Prototype I have the lowest overall efficiency while prototype III seems to give the best performance for high sunlight and can easily be assembled in the factory. The results obtained showed moreover that for low mass flow rates of ventilation, the use of a selective absorber is inappropriate for this type of solar collector, because it reduces the production of electrical energy. (HIGAZY.A.A)

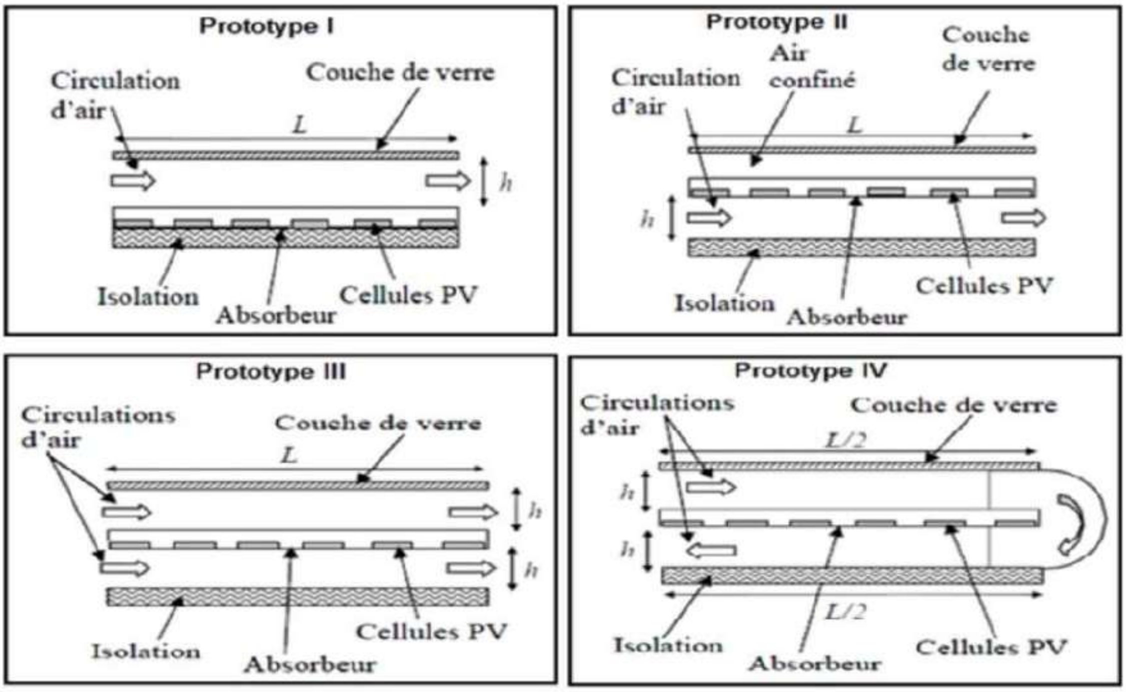


Figure (II.2): prototypes 1, 2, 3 and 4 of solar PV/T air collector (HIGAZY. A.A)

II.3 Dorouzi and al

Dorouzi et al. developed an indirect solar dryer assisted with a PVT system that was based on a desiccant regeneration circle. Closed-loop air circulation was formed using a DC fan, an auxiliary heater regulated the drying temperature, and a desiccant bed absorbed the exhaust air mist. In this work, calcium chloride solution as the desiccant fluid flowed freely over the PV panel to attain the excess heat and became regenerated. It is operated when the air relative humidity (RH) exceeds the set point. The results indicated that the proposed dryer has the capability to meet the entire electric power requirement when the drying temperature varies from 60–65°C and the RH set point for the regeneration circle activation is 28% of drying of the tomato. Figure bellow depicts the schematic view and a photograph of the developed system. (Shiva Gorjian and al, 2020)

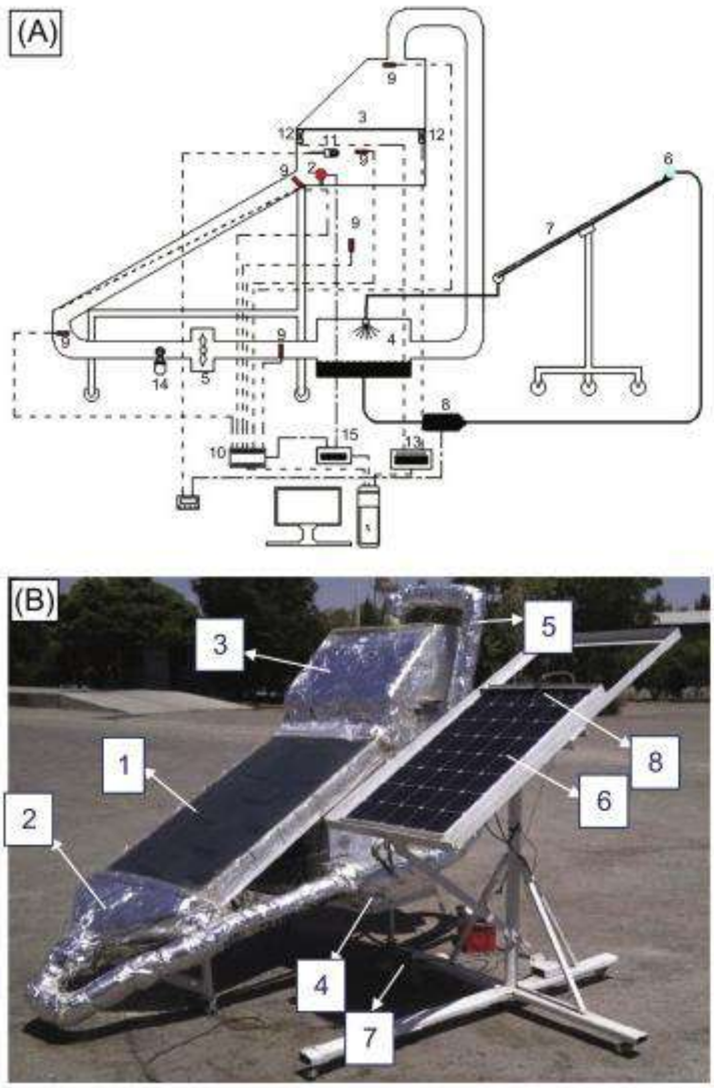


Figure (II.3): An indirect solar dryer assisted with a liquid desiccant-based PVT collector: (A) Schematic view of the experimental test rig, (B) A photo of the system including a solar collector (1), air entrance to the collector (2), drying chamber (3), liquid desiccant bed (4), connecting tube (5), PV panel (6), regeneration system pump (7), and distribution pipe (8) (Shiva Gorjian and al, 2020)

II.4 Joshi and al

Joshi and al. evaluated the thermal performance of a hybrid PV/T air collector system and analyzed two types of PV module, namely, PV module with glass-to-tedlar and glass-to-glass for composite climate of New Delhi. A schematic view of the PV/T air collector is shown in Fig. 22. They found that the back surface temperature is higher in glass-to-glass PV/T air collector than in glass-to-tedlar PV/T air collector. The hybrid air collector with PV module glass-to-glass exhibits better performance in terms of overall thermal efficiency. Overall thermal efficiency of glass-to-glass PV/T air collector is better compared with glass-to-tedlar PV/T air collector. Overall thermal efficiency decreases with increase in length of the duct in both cases and increases with the increase in the velocity of duct air.

(Ali Najah Al-Shamani, 2014)

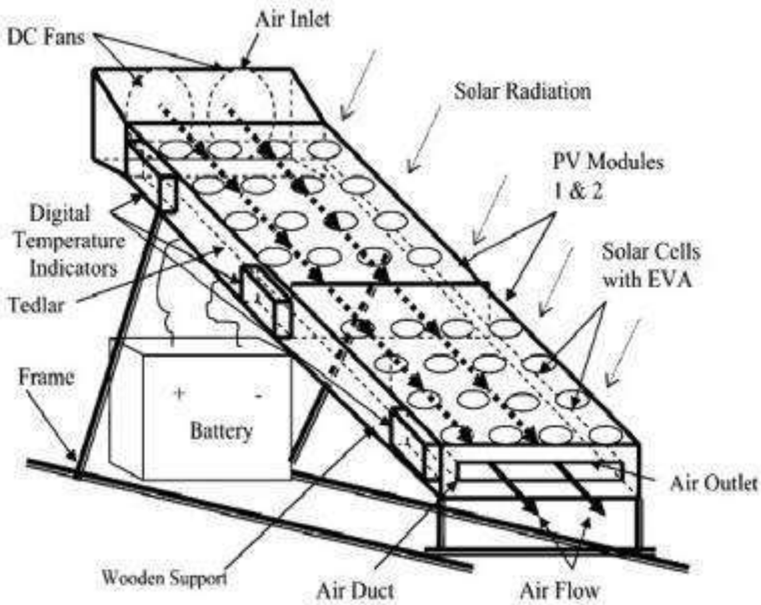


Figure (II.4) Schematic diagram of hybrid PV/T air collector (Ali Najah Al-Shamani, 2014)

CHAPTER III: Practical study

III.1 Introduction

To execute the hybrid solar collector PV/T we must go through different stages of construction that we are about to discuss in this part of our study; we designed and built two prototypes, the difference between each one of them is placing the photovoltaic panel on top of the thermal collector instead of the glass. The idea is to create a space that allows airflow which could cool down the PV cells and increase the performance of the panel.

The stages contain many operations like cutting, folding…etc.

However in order to know for sure if our experiment is successful we measured the performance of the hybrid solar PV/T and the thermal collectors, comparing them to one another.

The work was done at the technology lobby workshop at the faculty of medicine and material science at Kasdi Merbah university of Ouargla during March /May 2022.

III.2 Description of equipment used in construction of the prototypes

- ### Introduction

In order to complete the construction of the prototypes we used many tolls we are about to discuss in this part of the study.

All the equipment used were located at the technology lobby workshop and the tolls are from the same company called CIDAN.

- **Guillotine shear:** it's a manual cutter allows us to cut sheets of metals like iron, aluminum…etc. the cutter used is a **CIDAN** 07CM 0992 10031 24769 C9 299; the machine contains sheet support, a tall blade and a handle that controls the blade.

Figure (III.1) Guillotine shear

- **Universal sheet metal bending machine:** this machine is used to fold different types of metals, the manual folder is a **CIDAN** N/I: 24796 C9 300 N/S: 7320-0992, it contains a sheet support and 2 handles one is for fixing the sheet in place and the other is to fold and both of them is manual.

Figure (III.2) **Universal sheet metal bending machine**

III.3 The materials used

Figure (III.3) **Galvanized steel**

Figure (III.4) **Polycrystalline PV**

Figure (III.5) Polyester

Figure (III.6) Aluminum

III.4 Operating mode

In order to solve the problem that we discuss earlier in this paper we must construct two very similar but different prototypes; the difference between each one of them is the placement of the photovoltaic panel one is on top of the thermal collector and the other is separated from the thermal collector.

For the sake of our experiment we followed the stages bellow:

1. **Measuring**: we measured two sheets of galvanized steel, 68cm/100 cm and a 10.8cm on the sides of them; this will create the base of the collectors.

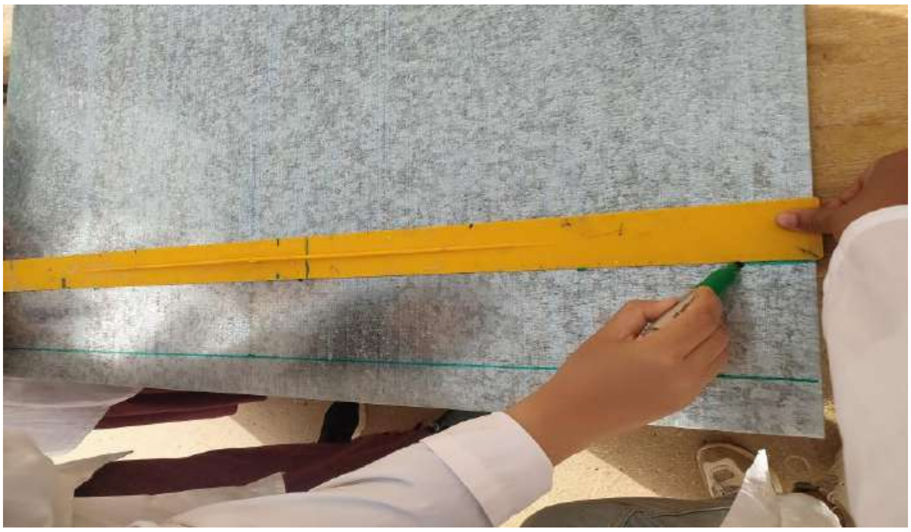


Figure (III.7) Taking all the necessary measurement

2. **Cutting:** using the guillotine shear cutter to cut the sheets to the desired shape which is a diagonal 68cm/100cm each.

Figure (III.8) Cutting the steel sheets

3. **Folding:** the ages of the base will be created by folding them and we used for that the universal banding machine.

Figure (III.9) Banding the steel sheets

Figure (III.10) The final shape of the base

4. On this stage we are going to measure and cut the polyester and the purpose of it is to act as an isolation that goes inside the base and covers them completely as shown in the figures bellow.

Figure (III.11) Measuring and cutting the polyester

Figure (III.12) Placing the isolation in desired place

5. To cover the isolation on both of the bases we cut another pair of steel sheets measured 43cm/100cm and 42cm/100cm, using always the galvanized shear cutter.

Figure (III.13) The two steel sheets after cutting

6. At this point we started working on the absorber and the smallest pieces that goes inside the bases to cover the isolation inner edges; these pieces measured 8cm/100cm,each pieces was divided into 3 parts measuring 2cm-4cm-2cm those parts are going to be banded in a shape shown in the Figure. The absorber on the other hand is going to be cut into a 43/100cm and 42/100cm sheets and folded by 1.5cm. The shear cutter and banding machine are used.

Figure (III.14.15) The process of cutting

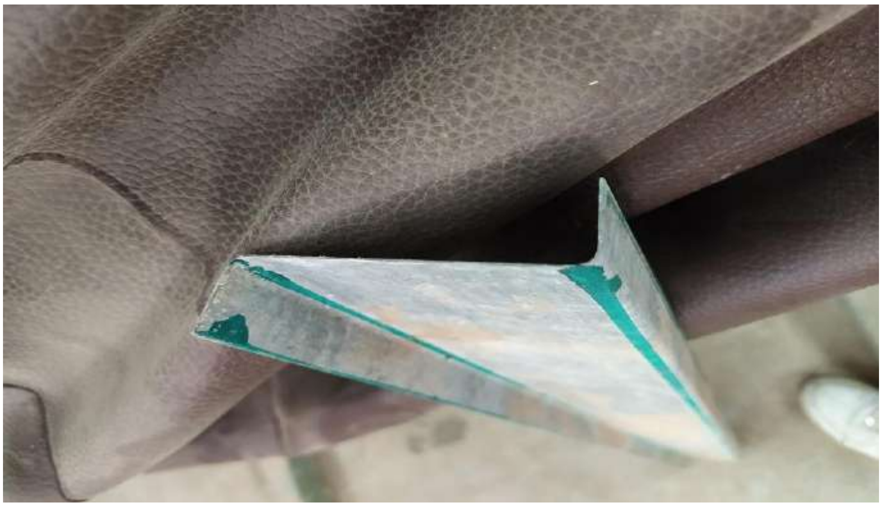


Figure (III.16) The shape of the edges pieces

Figure (III.17.18) The folding process of the absorber (aluminum)

Figure (III.19) The final shapes of the absorbers and the inner pieces

7. **The installation:** in this stage we combined all the pieces of our collector starting by:

- Gluing the isolation on the inside of the bases covering all the edges properly; the goal is to limit heat loss at the collector as much as possible.

Figure (III.20.21) The placement of the isolation in the prototypes

- Using the steel pieces in stages 5 and 6 to cover the isolation completely.

Figure (III.22.23) The covering process

- Gluing the parts using silicon, the prototypes should be given an amount of time to dry properly so we can move to the next stages of construction.

Figure (III.24.25) Gluing the parts of the prototypes

8. While waiting for the glue to dry on the bases, the measurement of the outer edges was done. We cut and folded four pieces consisted of 42/3cm each and eight others 3/2cm. each part was divided into three section and that's help with folding process (view the figures).

Figure (III.26.27) Cutting the outer edges

Figure (III.28.29) Folding

9. Afterwards we put the absorber assembled in stage 6 remaining pieces in their relevant place as displayed in the figures bellow and secure them with silicon.

Figure (III.30.31) Placing the aluminum and smallest pieces on the prototypes

Figure (III.32) The outer edges

10. After the glue dries we paint the absorber a black matt color and that aid for a better absorbance of sun radiation.

Figure (III.33) Painting the absorber process

Figure (III.34) The prototypes

11. **11.** Finally we cover one prototype with glass this helps the radiation captured by the absorber to stay in thermal collector; and the other one with a photovoltaic panel, secure them with silicon.

Figure (III.35) Thermal collector

Figure (III.36) Hybrid PV/T collector

Two solar collectors were tilted with an angle of 31^{o} (latitude angle of Ouargla city – South East Algeria) with respect to the horizontal position facing south direction to receive maximum solar radiation

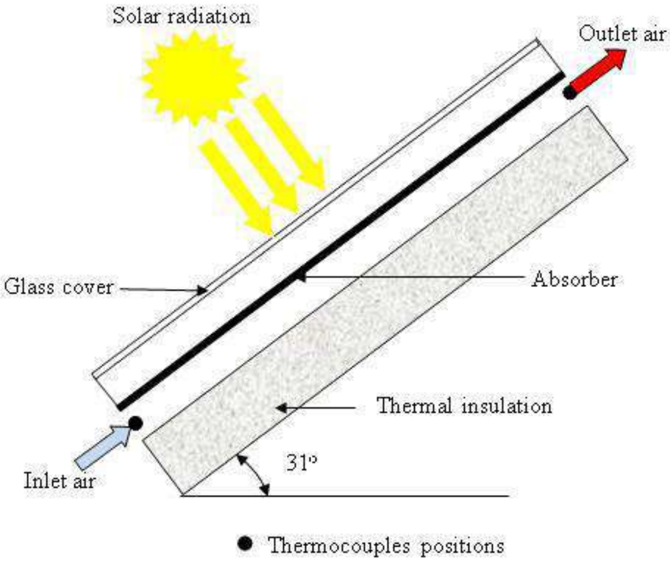


Figure (III.37) Schematic diagram of the Thermal solar collector

The absorber plate absorbs the radiation, which is transmitted through the glass cover, then the absorber plate's temperature rises, and the heat is transmitted to the circulating air by forced convection, raising its temperature. The air is heated along its passage and loses some heat to the glass due to atmospheric convection.

III.5. Performance study

The direction of our study is to calculate the performance of the hybrid PV/T collector and compare the results with the thermal collector and the photovoltaic placed separately; the study is done on a dual mode solar dryer vacuum function. The dryers were attached to fans that get electricity from the photovoltaic panels.

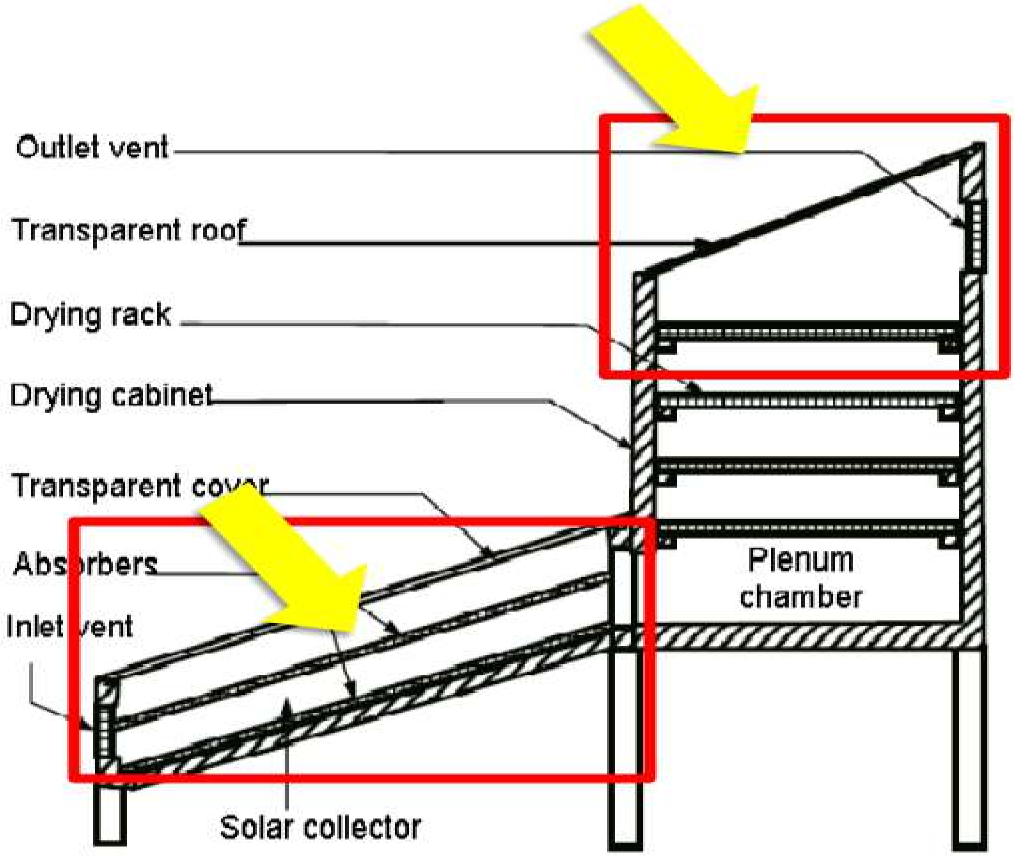


Figure (III.38) Mixed solar dryer

Figure (III.39) Fan

III.5.1. The equipment used in performance study

To achieve the goal we need to calculate the performance; this operation requires studying of the electric current and the power of both prototypes as well as monitoring the changes of the radiation and the speed of the fan.

However this part needs different equipment that aids our research to be accomplished the right way.

- **Voltmeter/ amperomtre:** This device measured both the power and the current electricity by attaching it with cords.

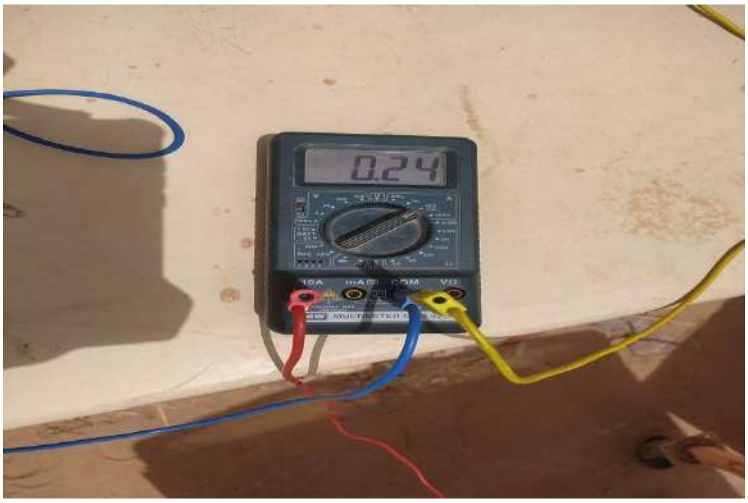


Figure (III.40) Voltmeter

- **Resistance:** the resistance helps with protecting the voltmeter from any potential electrical damage.

Figure (III.41) The resistance

- **Pyranometre:** A pyranometer is a collector that converts the global solar radiation it receives into an electrical signal that can be measured. Pyranometers measure a portion of the solar Spectrum. (Jarraud M, 2014)

  The measurements are display on an indicator.

Figure (III.42) Pyranometre

Figure (III.43) indicator

- **Velocity and temperature measuring device:** it is used to measure both the speed and the temperature

Figure (III.44) Velocity and temperature measuring device

III.6. Measurements

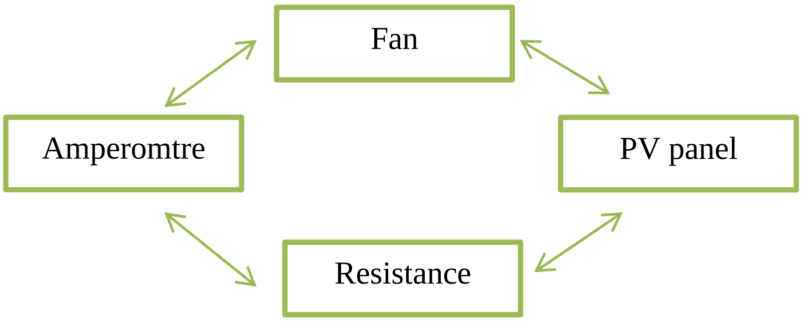
The study was accomplished on 16/05/2022 in Ouargla.

We designed a circuit that connects the prototypes with the amperometer, the resistance, and the fan together; as demonstrated in the figures bellow we covered the door of the dryer with polyester to prevent the hot air from leaking outside.

Figure (III.45) The circuit of the PV/T Collector

Figure (III.46) The circuit of the thermal and PV saperated

This circuit presented in this work:



III.7 Efficiency of the collector

The total efficiency of the PV/T collector is defined as the summation of the thermal and PV efficiencies. This is displayed in the following equation:

$$\eta_{\text{Total}} = \eta_{\text{Thermal}} + \eta_{\text{Electrical}} \qquad \textbf{(III. 1)}$$

III.7.1. Thermal Efficiency of the collector

The thermal efficiency of the collector is defined as the ratio of useful collected heat to the total incident solar flux. The equation of the thermal efficiency, η, of the solar bed is:

$$\eta_{Thermal} = \frac{\rho\, C_p\, Q\, (T_{out} - T_{in})}{A_c\, I} \qquad \textbf{(III. 2)}$$

Wher
e ρ is

T_{in}	Inlet air temperature (°C)
T_{out}	Outlet air temperature (°C)
ΔT	Temperatures gradient (Tout - Tin) (°C)
A_c	Collector area (m^2)
C_p	Specific heat (J/kg K)
ρ_{air}	Air volume mass (kg/m^3)
Q	Air volume flow rate(m^3/s)
R	Incident solar radiation(W/m^2)
η	Thermal efficiency (%)

density of air, Q is the air volume flow rate, Cp is the specific heat of air, Ac is total net collector area, and I is incident solar radiation. T_{in} and T_{out} are the inlet and outlet air temperatures of the collector, respectively. Because Ac is constant and assuming Cp and Q are constants for the range of working temperatures, the fractional uncertainty of the solar thermal efficiency of the bed is related to ρ, I and ΔT

III.7.1. Electrical Efficiency of the collector

The electrical efficiency ηe is:

$$\eta_e = \frac{I.V}{R.A_c} \times 100 \quad \textbf{(III. 3)}$$

Where

- **I: Amperage**
- **V: Voltage**

CHAPTER IV: Results and discussion

The figures are mainly a comparative study between the PV/T and the individual collectors; we compared the inlet and outlet air temperature of thermal collector, the amperage, and the changes of PV collector.

IV.1 Radiation:

For any solar system, it is important to know the quantity of energy received and its distribution in time. All solar collectors under study were at the same meteorological condition as shown in Fig (III.41)

We studied the changes in radiation throughout the day; we conclude that there are significant differences. The radiation reaches its highest point at 12:30 and then starts to decrease at the following hours. The maximum incident solar radiation was around 539 W/m^2 at 12: 30.

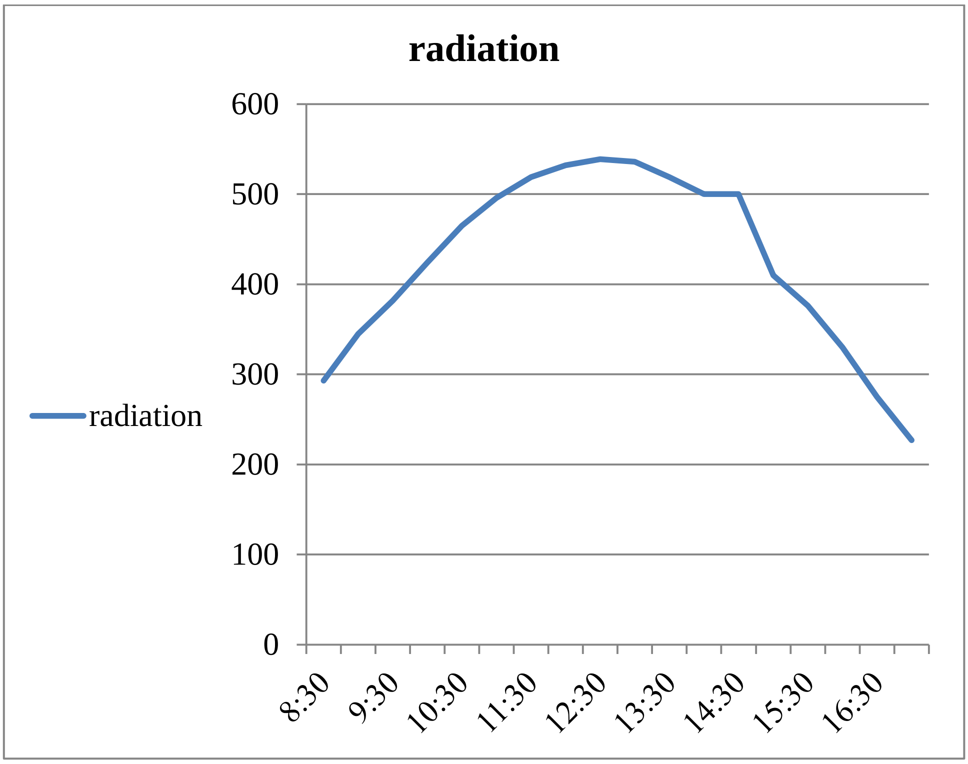


Figure (IV.1) The changes of the radiation

IV.2 Inlet and outlet temperatures

The inlet and outlet temperatures of the PV/T collector are presented in Figures bellow

In this case we see a little difference in the temperature, still the separated prototype is higher and that's because of the glass covering the absorber it holds the sun radiation better than the PV/T which does not contain glass.

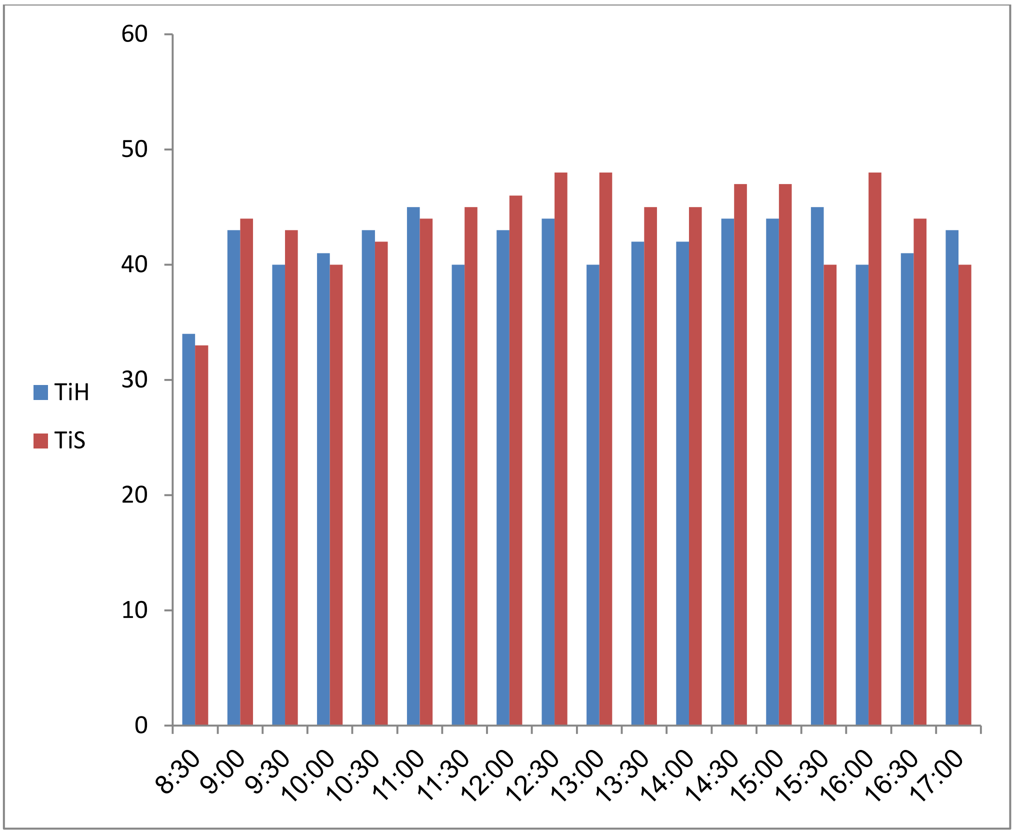


Figure (IV.2) The inlet temperature

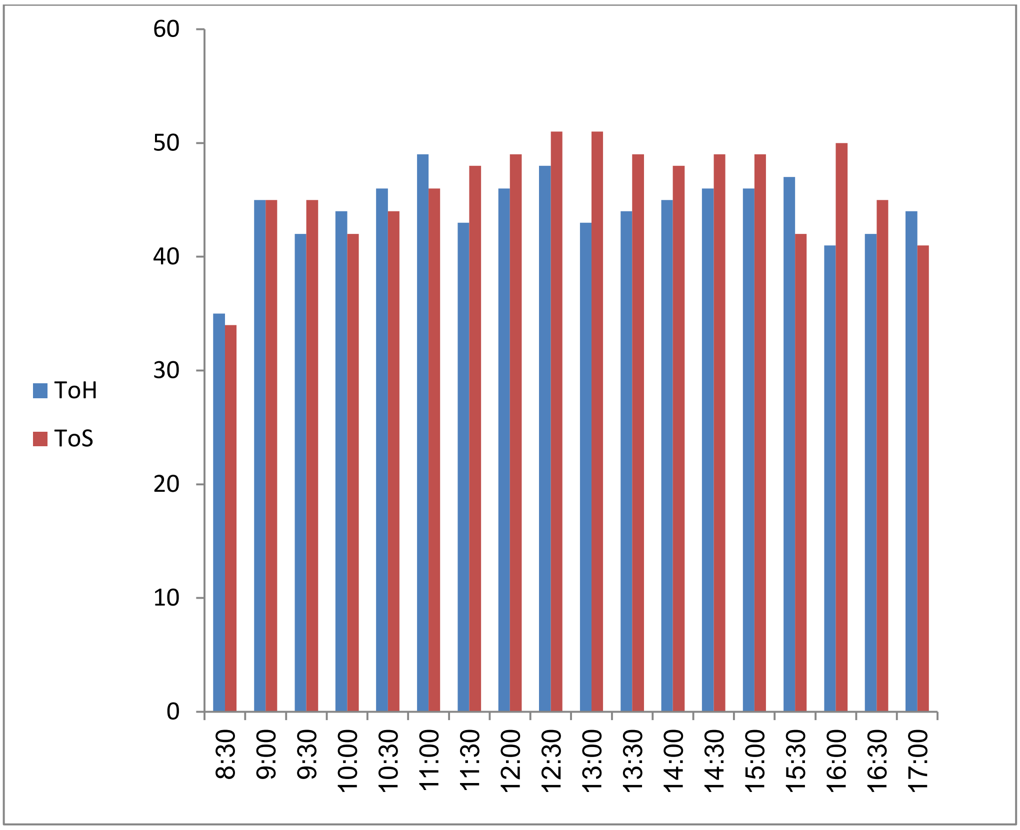


Figure (IV.3) The outlet temperature

TiH: inlet temperature of the hybrid PV/T **TiS:** inlet temperature of the separated module

ToH: outlet temperature of the hybrid PV/T **ToS:** outlet temperature of the separated module

IV.3 Amperage

For evaluating the electrical performance of the PV/T collector, the collector is connected to a electrical fan of solar dryer and power output of the collector along with global irradiation on the collector have been recorded. The emphasis is given to determine the effect of air circulation on the electrical performance, i.e. the advantage of PV/T collectors over traditional PV collectors in terms of electrical output.

To distinguish this difference, measurements are done with the fan being on and air circulating under the PV collector and the second PV no air circulation under the collector.

The Amperage that was recorded can be observed in the following figure:

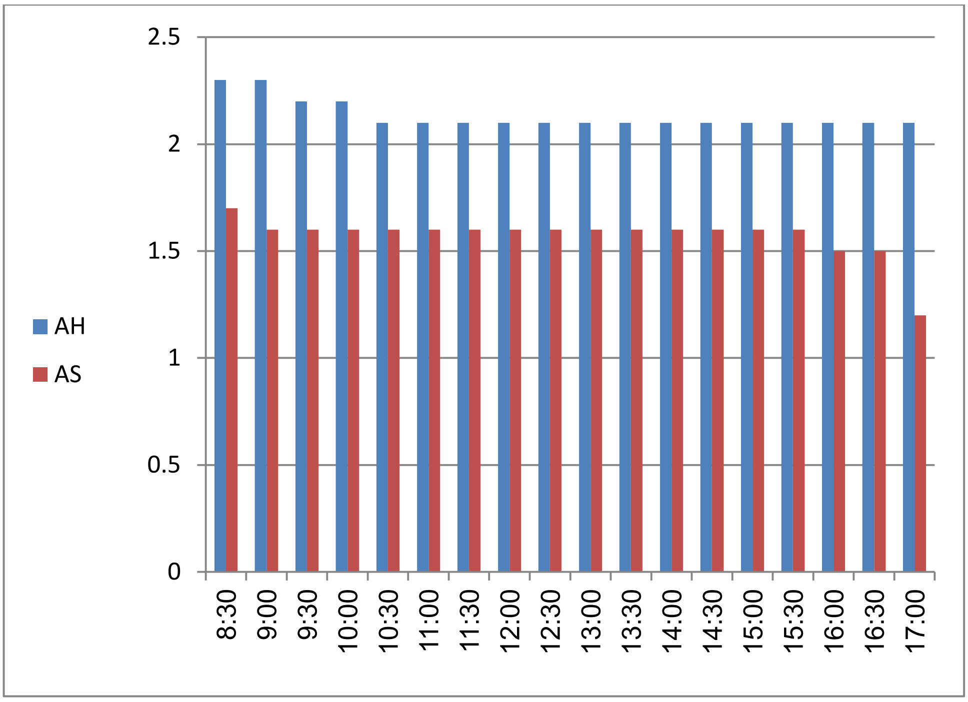


Figure (IV.4) the Amperage

AH: the amperage of the hybrid PV/T

AS: the amperage of the separated module

As expected, electrical power output of the first collector (Hybrid PV/T) is higher than the second collectors (PV separated to Thermal) due to the reason of the cooling advantage of combining the thermal and photovoltaic technologies; the air flow through the opening between the absorber and the PV panel which cools down the PV cells and increases the electrical output of the collector

IV.4 the performances

Based on equation (III.3), the electrical efficiencies of the collectors were calculated, and the result is shown in Figure (IV.5)

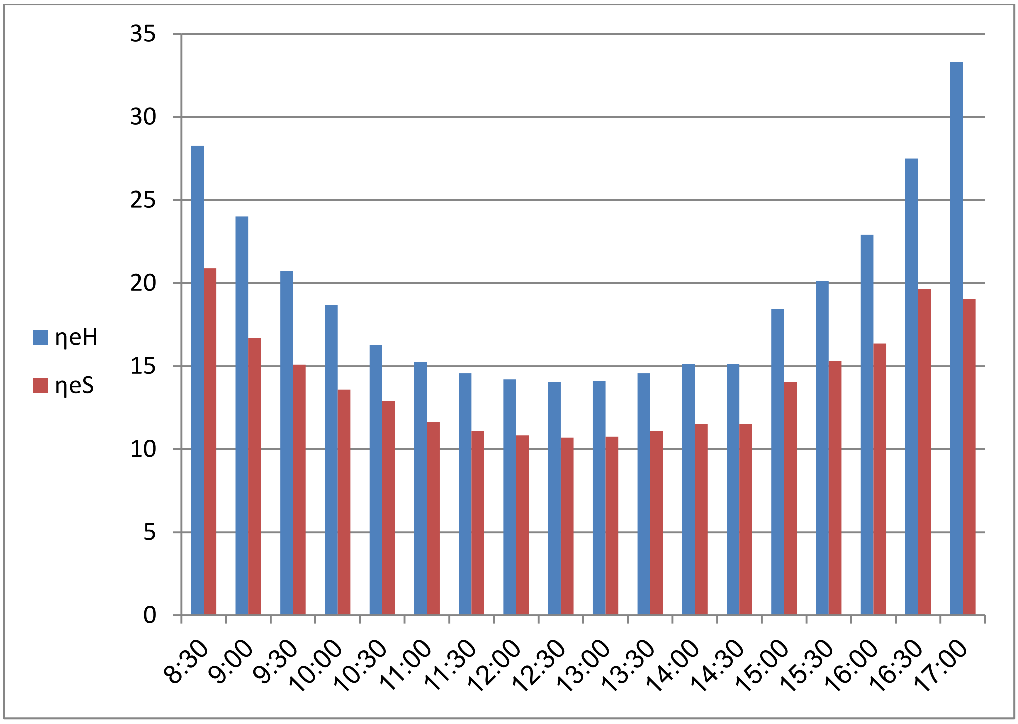


Figure (IV.5) Electrical efficiency of the collectors

From Fig (IV.5), it can be readily seen that the experimental electrical efficiencies of the collectors are as follows: reference case from 20.89 to 19.03 and PV/T from 28.26 to 33.31%.

Based on equation (III.2), the thermal efficiencies of the collectors were calculated, and the result is shown in Fig (IV.6)

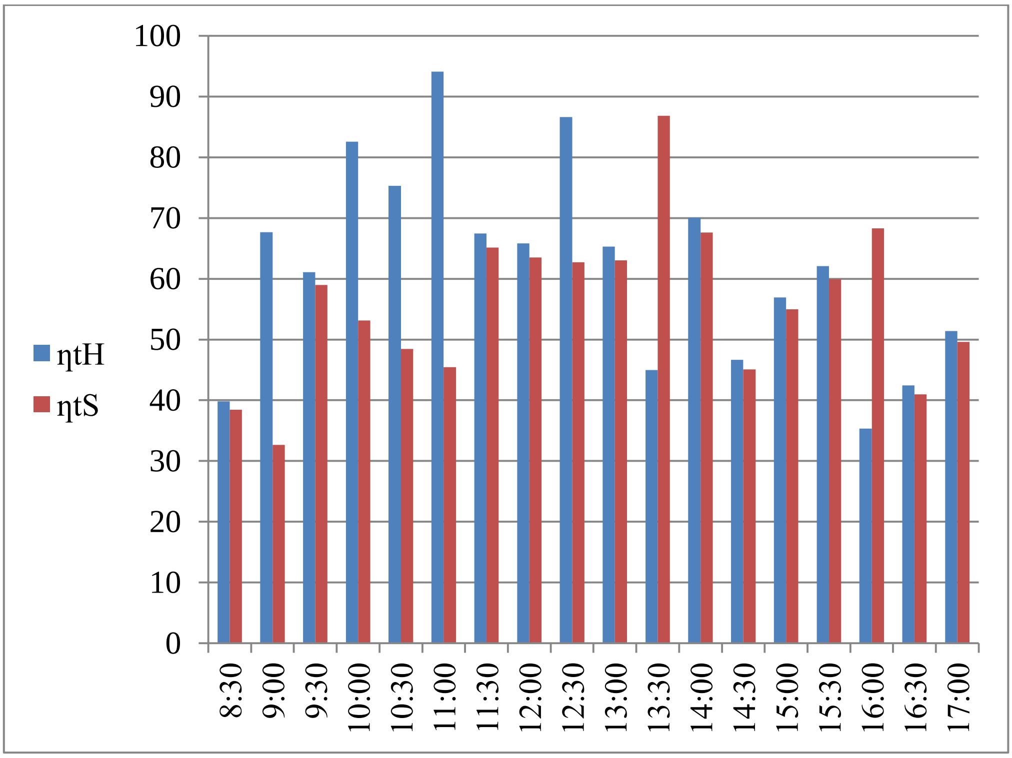


Figure (IV.6) Thermal efficiency of the collectors

In Fig (IV.6), it clearly appears that the thermal efficiency is maximized between 11:30 AM and 01:30 PM, which can be explained by the height of the solar radiation . The thermal efficiency variation curves follow even law that of the temporal variation of the total radiation, because they are interconnected by linear laws.

The values found for the thermal efficiency are from 39.45 to 49.63% in model PV separated to thermal , and from 38.82 to 51.4 % for the new integrated of PVT

Based on equation (III.1), the total efficiencies of the collectors were calculated, and the result is shown in Fig (IV.7).

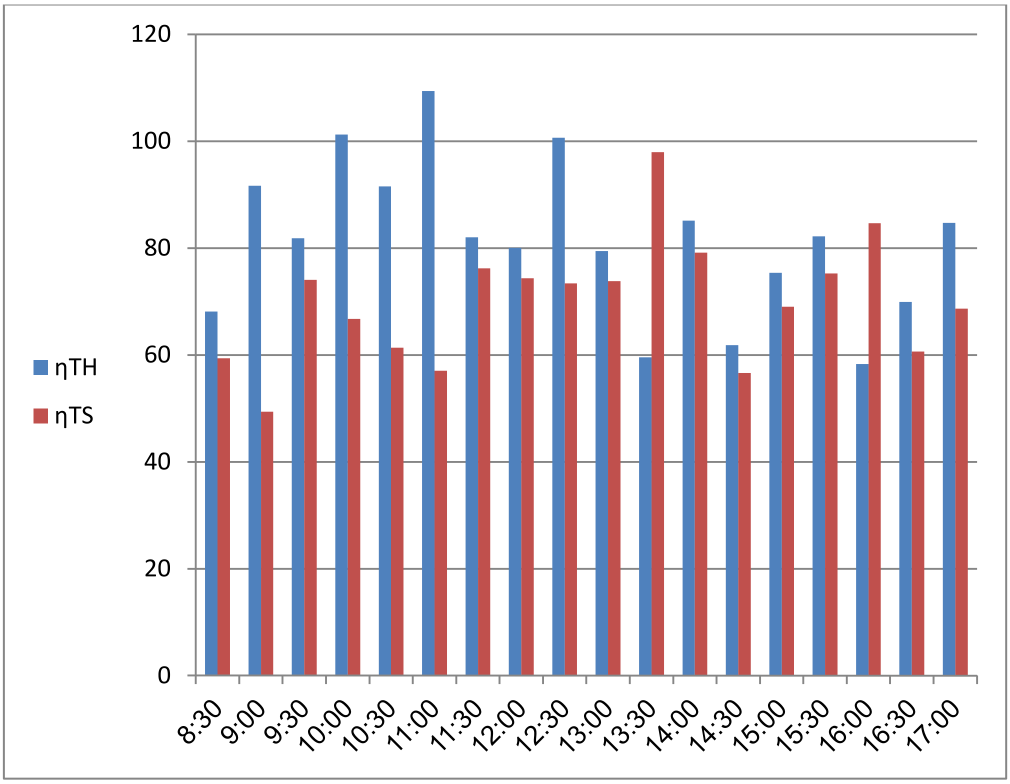


Figure (IV.7) Total efficiency of the collectors

The total efficiencies of the system are from 68.08 to 84.71 % for PV/T when the reference is from 59.34 to 68.66 %, as displayed in Fig (IV.7).

.The combined efficiency (electrical and thermal) of the PV/T collector is higher than that of the PV module and solar thermal collector alone.

Conclusion

We designed and construct a Hybrid solar PV/T collector in order to solve the problem that we discussed earlier in this paper and compare it with another one contains both solar panels but separated.

The work was realized at the faculty of medicine and materiel sciences, University of Kasdi Merbah Ouargla-Algeria.

All solar collectors under study were at the same meteorological condition and at the same time in the same day where all the measurement took place.

The results of the radiation shows that there is an increasing reaches the highest at 12:30 at 539 W/m^2 and after that time the quantity start drop down.

The inlet and outlet temperatures does not show a significant different between the two collectors under study but still the separated collector has a slightly high temperature and that's because of the glass covering it.

The amperage in the Hybrid PV/T collector is better than the separated one.

The average power of the PV/T panel is 10% higher than average power of conventional PV panel.

In general the thermal and total efficiency of the Hybrid PV/T gives better results than the thermal and photovoltaic collector separated.

We can say that the general results of the study are so promising and the experiment was successful.

Abstract

The work proposed in this thesis has been implemented within the framework of a study aimed at establishing a solar hybrid photovoltaic/thermal collector.

The latter consists of both electric power (used to power the fan) and thermal energy.

To achieve the optimal installation of the system, we made and installed two hybrid solar complexes (thermal and Photovoltaic), but the difference between them was in the position of photovoltaic panels. The first came a hybrid solar complex (contiguous, photovoltaic/thermal) connected, and the other separated.

These two prototypes were designed for the hybrid solar complex at the Faculty of Medicine and Material Sciences in the Technological workshop in Algeria. A series of experimental tests and on-site measurements were conducted on this prototype mixed solar dryer to test its operation and performance in actual operating conditions (climatic conditions of the experimental site). Their results were then compared to the fact that the optimum between them was the photovoltaic/thermal hybrid solar complex connected.

key word: Collector, thermal, photovoltaic, performance, solar energy, PV/T

الملخص

قد تم تنفيذ العمل المقترح في هذه الأطروحة في إطار دراسة تهدف إلى انشاء مجمع شمسي هجين كهروضوئي/حراري.

حيث يتكون هذا الأخير من كل من الطاقة الكهربائية (مستخدمة لتشغيل المروحة) و الطاقة الحراري.

و لتحقيق التركيب الأمثل للنظام ، قمنا بصنع و تركيب مجمعان شمسيان هجينان (كهر وضوئي /حراري) إلا أن الاختلاف بينهما كان في موضع الألواح الكهروضوئية. فجاء الأول مجمع شمسي هجين (كهر وضوئي / حراري) متصل، أما لأخر فمنفصل.

وقد تم تصميم هذان النموذجان الأوليان للمجمع الشمسي الهجين في كلية الطب و علوم المادة في البهو التكنولوجي. تحديدا في لولاية ورقلة بالجزائر . و أجريت مجموعة من الاختبارات التجريبية و القياسات في الموقع على هذا النموذج الأولي للمجفف الشمسي المختلط لاختبار تشغليه وأداءه في ظروف التشغيل الفعلية (الظروف المناخية للموقع التجريبي) . ثم تمت مقارنة نتائجهما متوصلين من خلالها إلى أن الأمثل بينهما هو المجمع الشمسي الهجين الكهروضوئي/الحراري المتصل.

الكلمات المفتاحية: مجمع حراري، كهروضوئي، فعالية، الطاقة الشمسية، كهروضوئي/حراري.

Résumé

Les travaux proposés dans cette mémoire dans le cadre d'une étude visant à établir un capteur solaire hybride photovoltaïque/thermique.

Ce dernier est composé à la fois d'énergie électrique (utilisée pour alimenter le ventilateur) et d'énergie thermique. Pour réaliser l’installation optimale du système, nous avons fabriqué et installé deux complexes solaires hybrides (thermique et photovoltaïque), mais la différence entre eux était dans la position de panneaux photovoltaïques. Le premier est venu un complexe solaire hybride (contigu, photovoltaïque/thermique) connecté, et l’autre séparé. Ces deux prototypes ont été conçus pour le complexe solaire hybride de la Faculté de médecine et des sciences des matériaux dans le hall technologique. en Algérie. Une série d’essais expérimentaux et de mesures sur place ont été effectués sur ce prototype de séchoir solaire mixte pour tester son fonctionnement et sa performance dans des conditions de fonctionnement réelles (conditions climatiques du site expérimental). Leurs résultats ont ensuite été comparés au fait que l’optimum entre eux était le complexe solaire hybride photovoltaïque/thermique connecté.

Mot-clé: Capteur, Thermique, photovoltaïque, performance, énergie solaire, PV/T.

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