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A Review and Analysis of the Effects of Colors of Light On the Performance of Solar Photovoltaic Panels

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Abstract: Solar energy is quite simple as the energy can be obtained from the sun directly. Solar energy is categorized as one of the best renewable energy since it does not emit carbon dioxide and because of unlimited supports from the sun. In this paper, three main sections of solar technologies like photovoltaic solar panel, concentrating solar power, heating and cooling system that is available present days have been investigated. In the second part of this research, an experiment has been carried out to evaluate the effects of colors of light on the performance of solar photovoltaic panels. Different colors of light having different wavelength, resulting in different frequency and hence different energy. In general, the solar spectrum influences the performance of the solar panels. The results show that the solar panels are influenced more by the red color of light. This report will start by detailing the three main solar technologies, followed by the testing on the colors of light with the solar panels

Keywords: Solar Technology, Photovoltaic, Concentrating Solar Power, Heating and Cooling System, Plank's Equation, Wavelength

1. Introduction

Sun is an intensely hot gaseous sphere with a diameter of 1.39×109 m which is about 109 times of the earth. The sun is at the center of the solar system and is about 1.5×1011 m away from the earth. The energy which is produced by sun is solar energy is an important source of renewable energy. Today's technology allow us to use this clean abundant renewable energy to provide heat, light, hot water, electricity, and even cooling for homes, industries and businesses. There are three primary technologies which are Photovoltaic (PV), Concentrating Solar Power (CSP), and Heating and Cooling System (HCS) in present solar systems.

Alexandre- Edmond Becquerel is the first person who discovered the PV effect in 1839 [1]. The first panel was built in 1883 by Charles Fritts but it shown only 1% efficient. The PV power was primarily thought to be unworkable due to its expensive cost and poor output. . In 1957, Hoffman electronics increased the efficiency

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to 8%. Additionally, worldwide PV production surpassed 21.3MW in 1983 and the global capacity was increased to 40,000 MW in 2010. Solar PV is becoming widespread due to their ability to absorb energy from sun rays to produce electric power for homes and commercial buildings. PV panels are the devices that consist inside the PV systems and it is used to convert light energy directly into electricity. Furthermore, they are frequently called as solar panels because the source of light used is from the sun. The PV systems is operated by the sun energy and this energy is unlimited hence the PV fuel is completely free. The PV process is generating the electricity through the sunlight as the "photo" means light and the "voltaic" means producing electricity. PV is a clean, reliable and quite energy but they are relative expensive in term of cost. PV systems do not produce noise because there are no moving parts and they are also environmental friendly because they do not produce harmful contaminants to the environment. In addition, the energy used up in PV panel production produces ten times lesser carbon emission when compared to the technology of fossil fuels. PV panel is a trustworthy semiconductor product because it has lifespan more than thirty years. Materials such as silicon which is a non-toxic is used to create the solar panels.

CSP which is also called concentrated solar thermal uses reflective materials like mirrors and lenses to concentrate the sun's light energy and convert it into high-temperature heat. The generated heat energy creates steam to drive the steam turbine that generates the electrical power. CSP is different with concentrated PV, because concentrated PV is directly converting the sunlight to electrical power via PV effect.

There are various types of solar HCS included using solar energy to water, space, and piping. The solar energy system has a high equipment cost but low operating cost for daily uses. However, the equipment cost can be cut down by reducing the system's size. An active solar space heating system is shown in Figure 1 [10]; it is developed using the similar components with the domestic water heating system. The heating distribution system uses heated fluids as the input source. The hot air from the solar collectors is used immediately or stored for other purposes. It is able to leave the system idle while the system does not need to cool down. Moreover, Figure 2 [11] will provide a better understanding on how the HCS works.

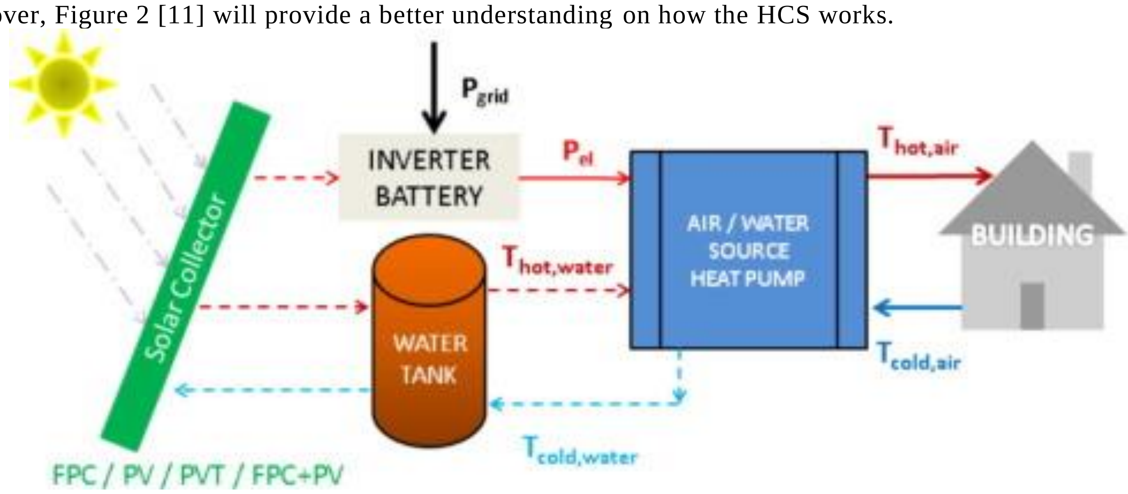


Fig. 1 - Space heating system [10]

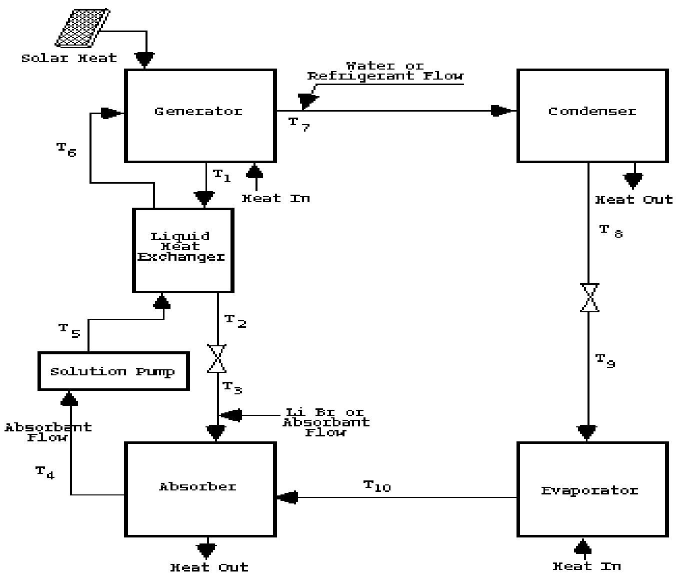


Fig. 2 - Schematic of solar cooling system, where T = system flow sequence [11]

The aim for this paper is to do the research on solar energy technology. There are three main solar energy technologies such as PV, CSP and HCS. Nowadays, solar energy is considered as an important renewable resource since it is clean, reliable and pollution free. Thus, solar energy will not contribute to acid rain, greenhouse effect and global warming. Besides that, solar energy is also a very sustainable resource since it can be used repeatedly as long as the sun is available. It is also a high efficiency and cost-effective renewable energy resource.

2. Solar PV Technologies

Solar photovoltaic (PV) has emerged as the most prominent renewable energy source among many types of renewable energy sources. Solar PV converts the light energy into electricity directly by using the PV cells. It is famous on its high efficiency and clean energy produced. This is shown in Figure 3 [1]. Several methods can be used to collect the light energy while the most recognized method is generating the electricity by using the Solar PV system (PV). Furthermore, light energy is considered as a renewable energy as the energy produced does not harm the environment and society. The solar energy conversion into electricity takes place inside panels which made uses of the depletion region in the P-N junction of semiconductors. The type of solar panel includes poly-crystalline, multi-crystalline, thin-filmed amorphous silicon and thin-film compound semiconductor [2].

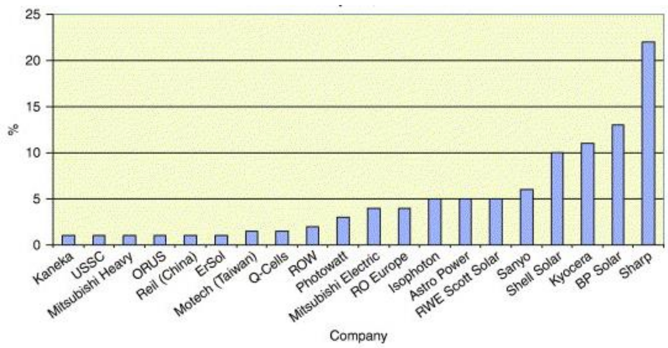


Fig. 3 - World-wide sales of solar panels 2002 [1]

2.1 PV system power generation

Several components like panels, mechanical and electrical connections or mounting components are consists in a PV power generation system. The rating for these systems is in peak kilowatts (kWp) where peak kilowatts (kWp) refer to an expected amount of electrical power to be delivered when the sun is directly overhead on a clear day. Basic PV system integrated with utility grid can be explained by the block diagram shown in Figure 4 [3]. From the block diagram, it shows that solar energy is converted into direct current (DC) power by the PV array. The power generated in the array is then flow towards the power conditioner with the help of the blocking diode. The power conditioner consists of a maximum power point tracker (MPPT), discharge controller and a battery charger. The function of maximum power point tracker is to assure that the maximum power generated by the solar PV array is removed. Meanwhile, the discharge controller is used to avoid or prevent the overcharging or over discharging of the battery bank [3].

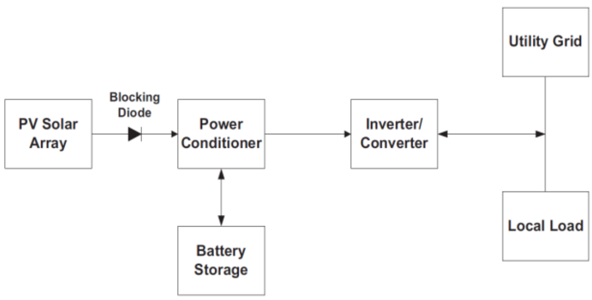


Fig. 4 - Block diagram for typical PV system [3]

2.2 Hybrid PV power generation

Hybrid PV power generation is the outcome of a combination of renewable energy (PV) with some other forms of generation such as diesel generators, wind turbine, etc. These hybrid PV power systems help to reduce and decrease the consumption of non-renewable fuel. Furthermore, renewable energy form like wind energy can be included. By referring to [3], replacing of the conventional energy source with a single alternative renewable energy is impossible. However, a combination of different type environmental free energy is required. Several researches and experiments have been conducted to study and develop these hybrid PV systems.

2.2.1 Fuel-cell-PV power hybrid system

A fuel cell-PV hybrid system is able to produce the hydrogen, store it and then convert these energy into electricity. This type of fuel panel is much suitable for spaceship applications. Hybrid fuel- panel system with wind and solar energy is shown in Figure 5 [4]. The PV panels convert sun energy into electricity during the daytime. The generated electricity is used to propeller the spaceship. Besides that, hydrogen and oxygen will be produced from the excess power through the electrolysis of water. In the night-time, the stored hydrogen and oxygen is then supplied to the fuel panel and from here the electric power is generated to propel the spaceship. Hence, this maximized the duration of the power available to the critical loads. Furthermore, this system is applicable and can be used for land based solar powered vehicles and Proton Exchange Membrane (PEM) is considered as the right fuel panel for this system. The operating characteristic of the hybrid system have to be improved therefore the power can be provided to the load for an extreme amount of time [4].

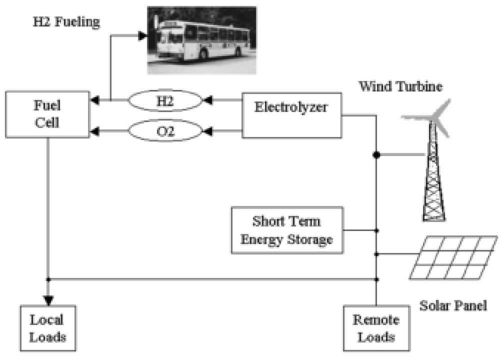


Fig. 5 - Hybrid fuel-panel system with wind and solar power [4]

2.2.2 PV/thermal hybrid solar technology

The PV/thermal hybrid solar system is also known as PVT. Both electricity and heat is produced from the combination of this system. Meanwhile, the PV acts as a thermal absorber in this combination. The basic of the hybrid concept is that a solar panel is used to convert the solar radiation into electrical energy with peak efficiency's range between 6-15%. Besides that, the peak efficiency will be different if different type of solar panel is used [5]. The heat from the solar energy is causing the cell's working temperature to increase. Furthermore, the electric grid can be improved when the PV module is cool using the fluid stream such as water or air. The heat pick-up by the fluid can be used for space heating or hot-water systems services. Usage of solar energy for producing service hot- water has a wider application than space generating in hot climate zone. The PVT is a better option when there is higher environmental temperature compared to the plain PV application. These hybrid systems offer several advantages such as minimize the thermal stresses and stabilize the solar cell-current characteristic. The use of renewable energy was promoted in many countries, has become a long-term national policy in many countries. With increasing demand of solar systems, the available spaces for the installation become limited. The insufficient place problem can be solved byusing the hybrid collector. Hence, this will dramatically increase the market potential of the hybrid collector. The main features of PVT are shown in Figure 6 [5].

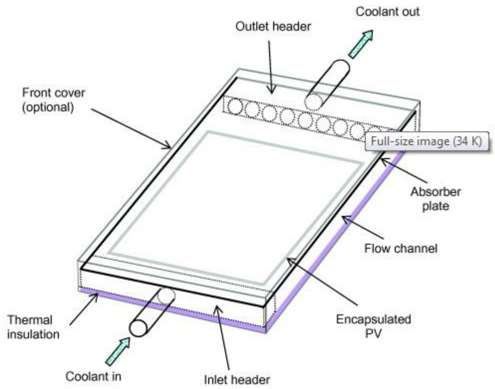


Fig. 6 - PVT collector [5]

2.2.2.1 Liquid PVT Collector

The liquid PVT collector is almost similar with the flat plate collector water heating system. Metallic sheet-and-tube absorber is used as the absorber materials in this type of PVT collector. The advantage of using this kind of absorber is it helps to reduce the weight and it's simplifying the manufacturing process. Besides that, the investment will be lowered due the reduced of material. Figure 7 shows the schematic of PVT/air collector [6].

2.2.2.2 Air PVT Collector

A PVT/air system is less efficient compared with the PVT/water systems. This is because of the thermo-physical properties of water are more higher compared to the air but the PVT/air systems have been used in most of the practical applications due to it lowers the operating cost and minimal use of material compared to others system.

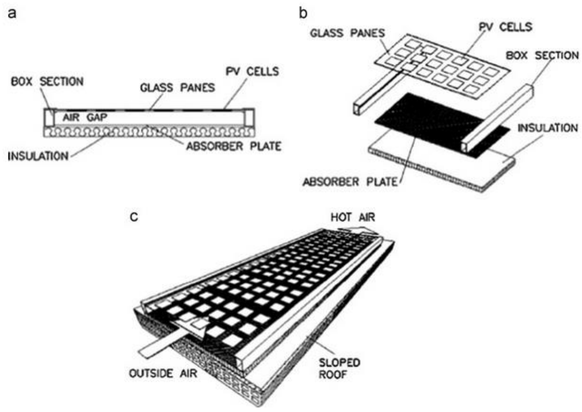


Fig. 7 - Schematic of PVT/air collector [6]

2.2.2.3 Building-integrated air PVT (BIPVT)

Building-integrated air PVT (BIPVT) is a reliable system because it's has higher constancy in lowering the environment impact. BIPTV system consists of PV module, tubes that act as absorber collector, glass cover and an insulated container. This type of PVT was recognized better to be installed on top of the roof or multi-functional facade because heat, light and electricity can be produced simultaneously from there. It is proven that this system is able to save the annual electrical energy consumption of the building.

2.2.2.4 Concentrator PVT System (CPVT)

Concentrating PVT system is a system which is able to work at high temperature. This method can be considered promising as the reflectors have lower cost relative to solar cell. The power from a solar panel can possibly be increased when a combination of CPVT with concentrating reflectors is used. Figure 8 [6] shows the schematic of concentrating PV/T collector.

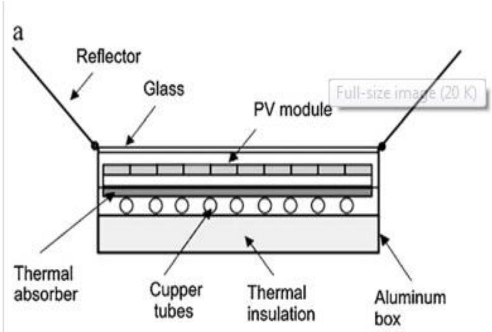


Fig. 8 - Concentrating PV/T collector [6]

3. Concentrating Solar Power (CSP)

CSP generating the power from high temperature heat by using concentrating solar collectors. CSP plant consists of solar field and power block. Solar field refers to the arrays that arranged in a certain manner and each of the arrays will consist of modules or concentrators. The sun's heat is concentrated by concentrators and reflects it to a receiver in order to generate a heat at medium or high temperature. The fluid is then passed through the receiver's tubes and produces the electricity from generators in the power block. In some cases, storage system is used to store a part of concentrated heat so that the electricity can still be produced in the condition of an insufficient sunlight. It is also possible for CSP to be hybridized with the fossil fuel in generating electricity since this method can help in improving thermal efficiency and reduce the cost of CSP technology.

There are four types of CSP technologies which is shown in Figure 9 [7] that have been widely used nowadays such as solar tower power, parabolic through collector, parabolic dish and linear Fresnel collector. Since parabolic through collector and linear Fresnel collector technologies concentrating sun's heat along the focal length of the collector, therefore they are known as line focus technologies. Parabolic dish and solar power tower technologies are categorized as point focus technologies since they can concentrate the sun's heat on a point at the dish or at the tower.

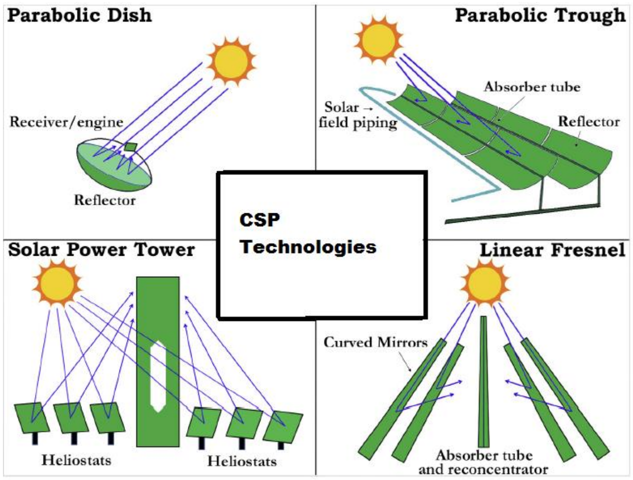


Fig. 9 - CSP technologies [7]

3.1 Parabolic Trough Collector Technology

Parabolic through collector technology is a one axis tracking system. It makes use of millions of parabolic shaped mirrors as reflector to reflect the sun's light to a focusing system that running along the focus line. There is an aluminum or steel mobile collector aligned on north-south or east-west axis. In summer, the north-south axis can provide more energy while in winter the east-west axis direction can provide more energy. Tracking system is used to rotate the collector in order to track the irradiation of sun's energy. The collected sun's energy will then reflects onto the receiver tube that contains HTF such as molten salt, pressurized water or thermal oil. The temperature of concentrated heat is depending on the types of fluids. For example, the concentrated heat temperature can reaches to 550ºC for molten salt, 500ºC for pressurized water and 400ºC for thermal oil. Heat exchanger is used to exchange high temperature fluid with the working fluid of conventional Rankine cycle. Figure 10 [8] shows the schematic of parabolic through power plant.

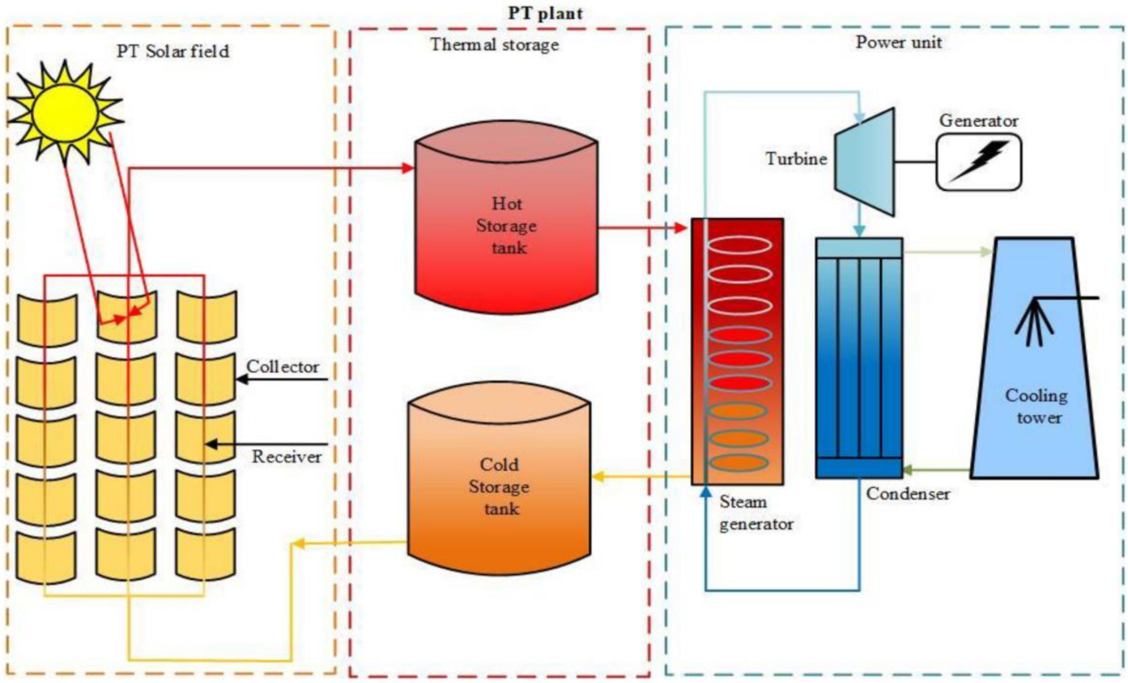


Fig. 10 - Schematic of parabolic through power plant with thermal energy storage [8]

3.2 Linear Fresnel Collector Technology

Linear Fresnel collector technology is also an axis tracking system that consists of a fixed collector and fixed linear receivers. The collector, which is normally in parabolic is made from 10 flat ground mounted mirrors. The purpose of this collector is to concentrate the irradiation of sun's energy by rotating based on the sun's position. The concentrated sun's energy is then reflected onto the linear receivers that consist of a long coated absorber tube. The purpose of using fixed receiver in this case is due to the flexibility of fixed receiver in accommodating with different types of HTF. For linear Fresnel collector technology, no heat exchanger is required. For example, if water is chosen to be a HTF, concentrated heat will convert it directly into saturated steam at the temperature of 250°C inside the receiver tube. This technology does not need piping system and its on-site installation is considered easy and faster. Besides that, it also has a higher mirror surface per receiver compared to parabolic trough collector technology.

3.3 Solar Power Tower Technology

Solar power tower technology is a two axis tracking system. It consists of a number of circular arrays (heliostats) that are flat and in fixed position. Heliostat, which has a million of mirrors with sun tracking function, is used to reflect the irradiation of sun's ray to the central receiver that placed at the top of the power tower. The transfer medium will absorb the heat and produce a superheated steam which can be used in the Rankine cycle to drive the conventional generator. In order to have a high optical efficiency so that the cost of solar field can be reduced, it is important to reduce the blocking and shading effects of the heliostats. Basically, there are three difference configurations based on heliostats arrangement. For first configuration, the receiver is placed vertically with the north facing heat transfer surface and the collector is placed in the northern hemisphere of the tower. For second configuration, the receiver is placed cylindrically with an exterior heat transfer surface and the collector is placed around the tower. For third configuration, the receiver encloses the heat transfer surface and the collector is placed at the north of the receiver. This technology required large amount of space for heliostats installation. The higher the number of heliostats, the larger the amount of energy can be produced. Receiver is able to operate under various types of HTF in order to produce concentrated heat with high temperature. The main drawback of this technology is the large consumption of water since huge amount of water is required to clean the heliostats and cool the exhaust wet steam from turbine.

3.4 Parabolic Dish Technology

Parabolic dish technology is two axis tracking systems that make use of the concentrator which is in a parabolic dish shape to reflect the irradiation of sun's ray to the central receiver found at the focal point of a parabolic dish. The sun's light is then used to produce a high temperature heat which can reach up to 1000°C. The generating unit inside the receiver is used to convert the high temperature heat into electricity. This receiver is normally referred to stirring engine or micro turbine. The HTF that used to drive this type of receiver are hydrogen and helium. This technology has the highest overall efficiency among all CSP technologies. The reason is that there is a reduction in thermal losses due to the attachment of generating unit to the receiver of each dish. However, this technology is unable to integrate with the thermal storage system to store the concentrated heat. Besides that, it is also almost not possible for this technology to hybridize with other source of energy to improve efficiency.

Table 1[9] shows the performance data of various type of CSP technologies. Some technical parameters are shown in Table 1 such as capacity, concentration, peak system efficiency, annual system efficiency, thermal cycle efficiency and land use. Parabolic through, linear Fresnel and solar power tower have the similar capacity which is in the range of 10-200 MWel. Parabolic dish has a smaller capacity compared to other CSP technologies. However, parabolic dish has a highest concentration and efficiency among all CSP technologies. It can achieve maximum system efficiency of around 29% [9]. Solar power tower required a higher land use because the installation of heliostats required more space.

Table 1 - Performance data of various CSP technologies

CSP	Capacity/ MWel	Concentration	Peak System Efficiency	Annual System Efficiency	Thermal Cycle Efficiency	Land Use/m^2 ($MW.h.a^{-1}$)
Trough	10-200	70-100	21%	(10-16)%	(35-42)%	6-11
Fresnel	10-200	25-100	20%	(9-13)%	(30-42)%	4-9
Power Tower	10-200	300-1000	23%	(8-23)%	(30-45)%	8-20
Dish	0.01-0.4	1000-3000	29%	(16-28)%	(30-40)%	8-12

3.5 Global CSP (GCSP)

Figure 11 [9] shows the global cumulative installed CSP capacity from year 2007 to year 2012. Based on the graph in Figure 11, USA and Spain dominate the market of installed capacity from year 2007 to year 2009 while Spain dominates the market of installed capacity from year 2010 to year 2012. In year 2012, Spain dominates around 69% of overall market of installed capacity. Spain builds the first plant in year 2007 and start the domination of market of installed CSP capacity until now. Middle Eastern and African (MENA) countries such as Algeria, Morocco and Egypt have an installed capacity of 20MW and 65MW in the year 2010 and year 2011 respectively. China starts the CSP technology since year 2012 and has an installed capacity around 2MW within that year.

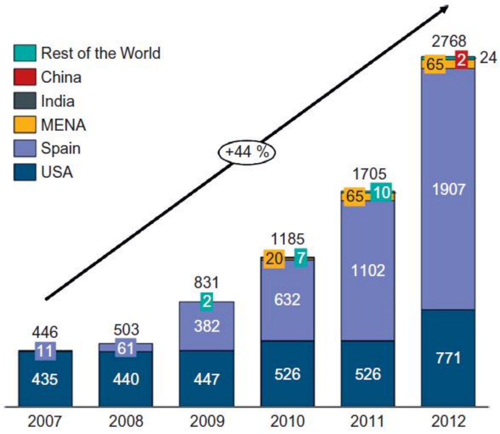


Fig. 11 - Global Cumulative installed CSP capacity, MW, 2007-2012 [9]

3.6 Heat Transfer Fluids (HTF)

HTF is the thermal carrier that used to collect the heat from the receiver. The use of HTF can be a direct method or an indirect method. In direct method, HTF is used directly to drive a turbine in order to produce the energy. For indirect method, heat exchanger is combined with the HTF to generate the steam. An insulated tank can also be used to store the HTF so that they can be used when there is an absent of sunlight. HTF can affect the efficiency and performance of the CSP systems. Low cost high performance HTF are recommended to reduce the overall system cost while maintaining its efficiency. In order to have a high performance, HTF should meet the desired physical or chemical characteristic such as high boiling point, high thermal stability, low melting point, low vapor pressure and low corrosion rate. HTF can be categorized into six groups which are gases, water, thermal oils, molten salts, liquid metals and organics. Figure 12 [9] shows the list of working temperatures range of each types of HTF. Molten salts is most widely used as HTF since they have high working temperature (mostly more than 500^{o}C), high heat capacity, low vapor pressure and low corrosion rate. Liquid metals are mostly used in high temperature solar plants due to their high working temperature. For thermal oils and organics HTF, their working temperature is the lowest among all types of HTF which is less than 400^{o}C. Thermal storage capacity is also an important thing that needs to be considered so that HTF are able to store the heat efficiently during night time.

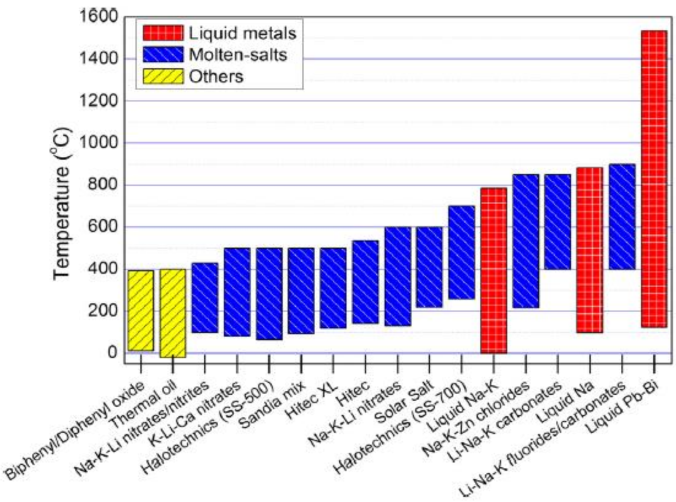


Fig. 12 - Working temperature range of each types of HTF [9]

4. Solar Cooling Systems

The wide use of air conditioner and refrigerator which worked using electricity has increased and encouraged the uses of fossil fuels to produce electricity. This situation will brings impact to the environment and upsurges the global warming. The solar cooling system was actually suggested 35 years ago. The main advantage for using the system is enable the operation of cooling system in the dry and desert areas and generation of efficient and economical cooling system. There are lot of different types of technologies to use solar for the cooling purpose. However, the absorption refrigeration is the most frequently implemented technology among these technologies.

4.1 Solar-powered absorption cooling machine

The cooling machine is operated with the high demand of solar energy supply. The operating environment of the cooling machine with solid absorbent is strictly to locate at the hot and dry areas as they can handle the high ambient temperature. The absorption cycle is actually called the cooling cycle with low-pressure section while desorption cycle is called as heating cycle in general form with high-pressure section. The cooling machine works to carry out absorption cycle during night and desorption cycle during daytime. Although there is no requirement to install the extra cooling equipment for the cooling machine with solid absorbent, but it requires a cold storage to power up during daytime. There is a common way to be discussed in order to improve the performance of the cooling machine with solid absorbent which is adding a reactor covered with steel wood. The components of the extra reactor are two steel pipes filled with strontium chloride or SrCl2 in short form.

There are four stages to operate the new implemented cooling machine. The stages are desorption, cooling, absorption, and heating. During the daytime, the reactor starts to heat by the sun and carries out desorption process. Desorption process drives out ammonia and stores it in the pipe. During the night, the reactor starts to carry out absorption process and to be cooled down. When the temperature of the cooling machine reaches to where the process happened, the absorbed heat will be sent into the pipes in order to operate the cooling machine in an opposite way. The temperature is dropped in the cooling section when the cooling machine operates in the opposite way. This improvement is still not perfect enough as a simulation study is carried out to show that the ammonia mass is increased in the ammonia reservoir during the daytime and it reached to the maximum during the night time when reactor stops to be heated.

4.2 Solar absorption refrigeration cycle

There is another type of solar refrigeration cycle which operates by using LiBr-H2O fluid. The input energy of the system is remained constant by enlarging the electricity operated compressor. The compressor can be located at the low pressure generator side to carry out double effect system in order to produce a simple and economic system. There are two sections divide the refrigerant vapours into two different ways where one is going to the condenser directly while another one is going through the compressor to increase the temperature. The temperature increased is then going to the heat exchanger in order to add the volume of the heat exchange to lower down heat load in the generator. The refrigeration cycle is not only advances in lower down the temperature difference between the heat transferring fluid and surroundings, it also helps in adding the heat to the system. The advantage of the system is able to improve the performance of the whole system as there is a higher amount of consumption of the energy [10]. Figure 13 shows the systematic scheme for refrigeration cycle.

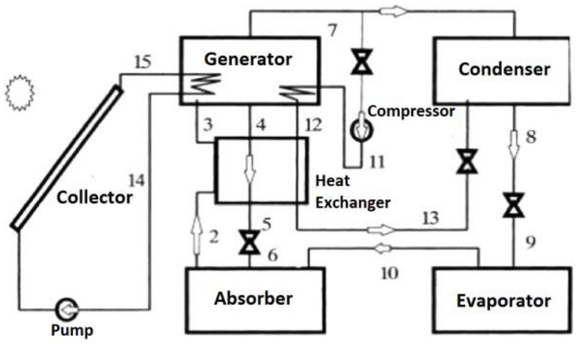


Fig. 13 - Systematic scheme for refrigeration cycle [10]

4.3 Solar hybrid cooling system

The solar hybrid cooling system is applied to overcome the problem of climate change by using low energy cooling at buildings. Solar cooling is an important solution to attain low energy cooling. In the first stage of the system, the generator is feed to energize the central equipment which is absorption chiller by using a generator water pump.

The cooling water pump sends the cooling water to the absorber and condenser. Meanwhile, the cooling tower rejects the heat collected by the system. The hot water temperature will be boosted by AH1 (auxiliary heater) if there is an insufficient solar heat gain.

For the desiccant dehumidification which is the second stage, the core equipment is the desiccant wheel which let the cooled process air passing through the system. The heat wheel is used for the cooling purpose in the desiccant wheel. Then, the process air is been further cooled by the supply air coil for the needed supply air environments. The absorbed moisture is reformed by using the heat coil and the reformative water pump sends the needed hot water. AH2 works in the same way with AH1 in the case if there is lack of hot water temperature. However, the fresh air fan and exhaust air fan are normally installed in order to maintain the process and consume air streams in this stage. In the next stage of the system, there are three common types of equipment which included chilled panels, passive chilled beams and active chilled beams. The cooling effect of passive chilled beans is generally depended on the natural convection while the cooling effect of active chilled beams is generally depended on the forced convection. Therefore, the active chilled beams need extra additional air fan to work for cooling. These two types of equipment are suitable to be used in this stage as they have the suitable cooling intensity needed by the system. They are set up inside the high technology workplaces and linked to the chilled water pipework of the absorption chiller in order to generate radiant cooling value to manage the flow rate of chilled water. For the last part of the system which is the solar energy collection, the solar collectors are replaced by flat-plate collectors. Figure 14 shows the schematic diagram of solar hybrid cooling system. They have the lower efficiency but it can estimates the range of capability of the system. The two gas auxiliary heaters are used as the back-up to prevent the lack of solar thermal gain for the first two stages of the solar hybrid-cooling system [11].

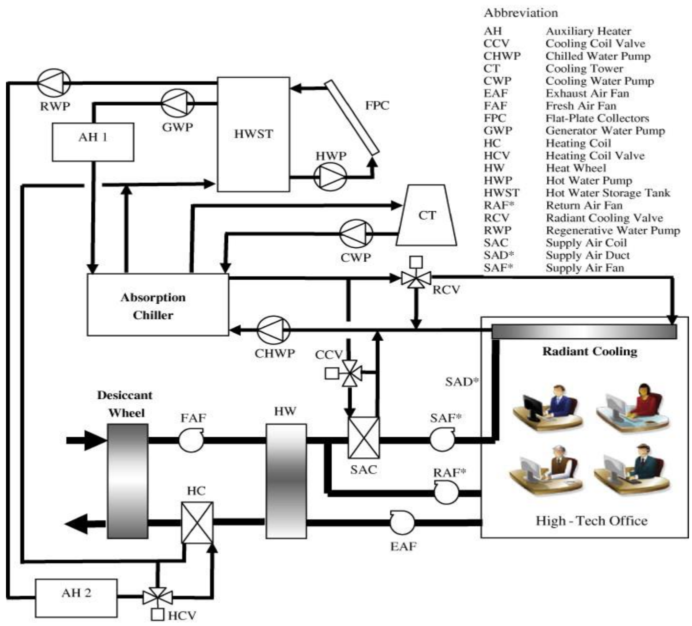


Fig. 14 - Schematic diagram of solar hybrid cooling system [11]

4.4 Solar Heating System

For the active systems, the collectors are collected the water or heat transfer fluid by pumping. This type of system is more difficult to be installed in the house as the system requires an extra space for the additional equipment. For the passive systems, they use the natural convection to collect the heat potable water and the transfer fluid. The passive systems are more easy and economical to be used.

4.5 Active Solar Heating System

4.5.1 Direct circulation system

The potable water is circulated from the storage to the collectors using a pump as shown in Figure 15 [12]. This can only works when there is sufficient solar energy in order to raise the temperature and return the heated water to the storage tank until it is required. To control the pump, the differential thermostat measures and matches the temperature at the solar collector and storage tank. The thermostat drives the pump when the different ranges of temperature occur. The collectors are suitable to put either above or below the storage tank as a pump is used in the system. Besides that, there is a spring loaded check valve to avoid the reverse thermo siphon circulation energy losses as soon as the pump is not able to work. The water delivered to the system is either taken from a cold-water storage tank or straight from the town water mains.

The direct circulation system is appropriate to be applied in the irregular freezing zone as shown in Figure 16 [12]. However, there is a process called freeze protection to protect the system for the extreme weather. There is an automatically draining wherever there is a freezing condition. The system uses the normally closed valve to separate the collector and external piping and uses the two normally open valves to drain it.

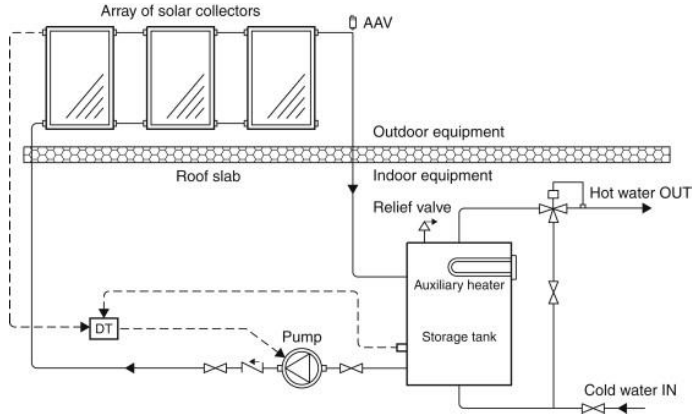


Fig. 15 - Direct circulation system [12]

4.5.2 Air water-heating system

The air water-heating system in Figure 17 [12] is actually the indirect water-heating system. The system is applied most frequently as it is mainly for pre-heating domestic hot water. It is a benefit in the unnecessary protection of the air either from boiling or freezing. It is also free, non-corrosive, and also does not degrade the heat transformation.

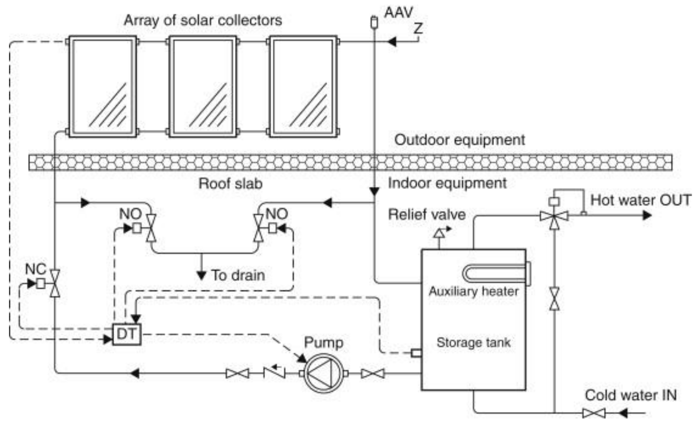


Fig. 16 - Freeze protection of the direct circulation system [12]

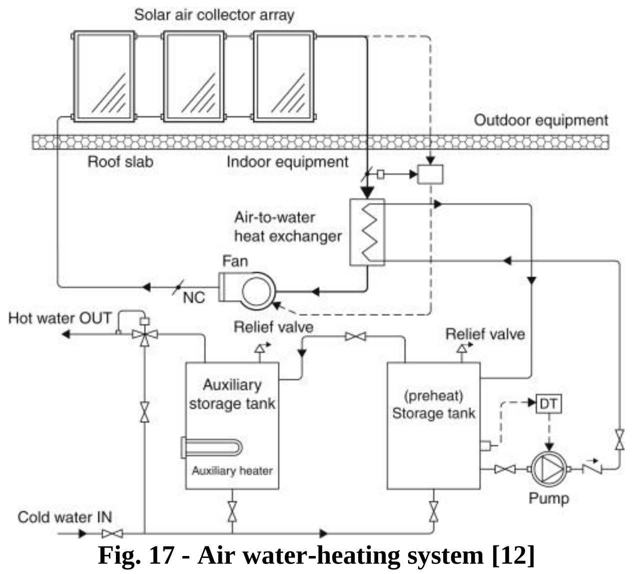


Fig. 17 - Air water-heating system [12]

4.6 Passive Solar Heating System

4.6.1 Thermosiphon system

The system uses the natural convection to deliver the heat potable water and transfer fluid from the collector to the storage tank. Whenever there is a raise of temperature which caused by the drop of water density, the thermosiphoning effect will takes place. The effect will cause the absorption of solar radiation occurs and thus the water is heated via collector. The cool water which is sunk will replaces the heated water before. The process lasts as the shining sun is presented. The pipe friction can be reduced by using a large pipe size in the system as shown in Figure 18 [12].

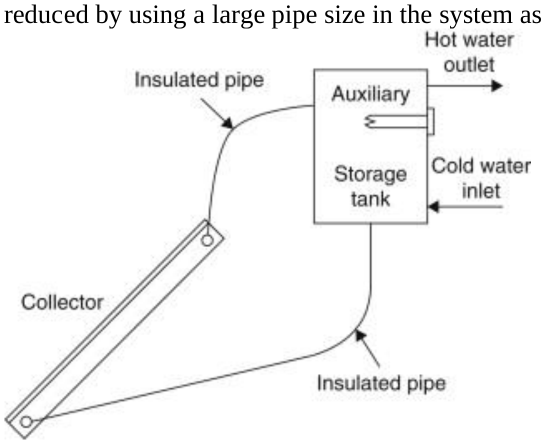


Fig. 18 - Schematic diagram of thermosiphon system [12]

4.6.2 Integrated collector storage system

The integrated collector storage system installs the hot water storage with the collector. In order to achieve the stratification of the system, the hot water is drained from the top part and the cool water is goes in the bottom part of the storage tank from the reverse side. Figure 19 shows how the system looks like [12].

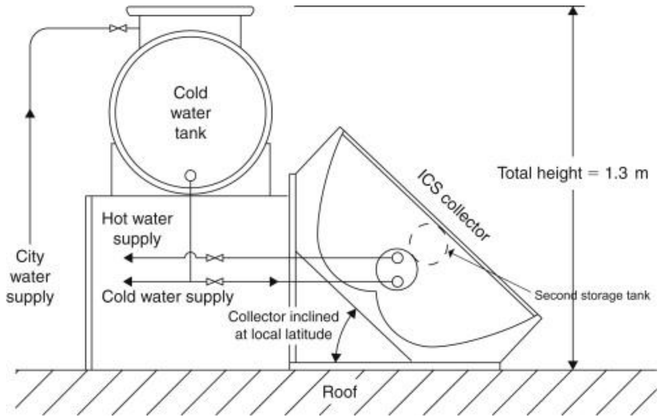


Fig. 19 - Integrated collector storage system [12]

5. Materials for Solar Cell

Silicon is a leading technology in making solar panel because their efficiency is high among materials for solar cell. The reason behind this is the low costing for thin film technology. By comparing the layers with mono and poly-crystalline solar panel they are much thinner, and it uses less materials. However, the efficiency of thin film technology based solar panel is still not high. Under thin film technology there are three materials have been given much attention are amorphous silicon, CdS/CdTe and CIS. The researchers are continuing to put more of their effort to enhance the efficiency. Polymer materials have many advantages such as lightweight, low cost and friendly to environment. The only problem of polymer materials is that their efficiency is very low comparing to other materials which is only 4% to 5%. Figure 20 shows the brief overview on materials of solar panel production.

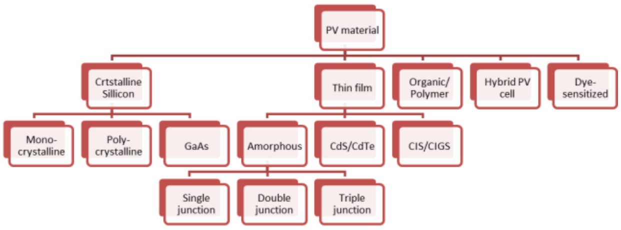


Fig. 20 - PV material chart [13]

5.1 Crystalline materials

Among the solar panel materials, crystalline silicon based solar panel has the highest efficiency. On top of that, silicon is the second easiest raw material that can be found on earth, so the supply can be easily available.

5.1.1 Monocrystalline panels

This type of material has been widely used in developing PV panel because its efficiency is 15 % higher when comparing to polycrystalline panels [13]. Monocrystalline solar panel has the highest efficiency with more than 20% comparing with other type of solar panel material. However, for commercialization, manufacturer claimed that the efficiency of monocrystalline solar panel is normally ranged between 15% and 17%. The unit panel of silicon is shown in Figure 21. In this process, high-purity, semiconductor-grade silicon is melted in a container which is usually a crucible made of quartz. It will change into n-type or p-type silicon as the impurity dopant atoms such as boron or phosphorus are added to the molten silicon in precise amounts. The electronic properties of the silicon are influenced. An exactly oriented rod-mounted seed crystal is dipped into the molten silicon. The seed crystal's rod is pulled up slowly and rotated synchronously. Extracting a large, single-crystal, cylindrical ingot from the melt is possible by accurately controlling the temperature gradients, rate of pulling and speed of rotation. During the crystal growth process, investigate and visualize the temperature and the velocity fields can avoid the occurrence of unwanted instabilities in the melt. This process is normally performed in an inert chamber such as quartz, or in an inert atmosphere such as argon.

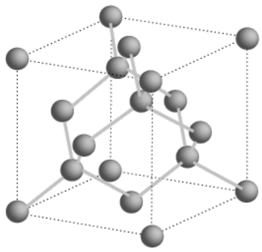


Fig. 21 - Unit panel of silicon [13]

5.1.2 Polycrystalline panels

This material can reduce the manufacture cost in developing PV module. However, polycrystalline solar panel is low in efficiency comparing with mono-crystalline panels and other developing materials. But its flaws in metal contamination and crystal structure are low compare to mono-crystalline cell. In order to produce polycrystalline, silicon is melted and solidified to orient crystals in a fixed direction. Then, the rectangular ingot of polycrystalline silicon is produced and is sliced into blocks, lastly into thin silicon wafer.

5.2 Wavelength versus Solar Cell

Solar panel involves the conversion of light energy into electrical energy. Light is made up from a packet of energy known as photons. Photos perform depends on the frequency, wavelength and color of light. When solar panel absorbs light energy, electrons from photons are excited to a higher energy states within the material and quickly relaxed back to their ground states. Figure 22 shows the situation when the light hit the p-n junction of the solar cell. Potential difference or an electromotive force (emf) is produced from the energy of these excited electrons. Electrical energy is formed when electrons are driven through a load by using this force. The light absorbing materials can affect the effectiveness of solar cell. White light is emitted from sun in the form of electromagnetic waves. The white light is the combination of several colors of lights such as red, orange, yellow, green, blue and violet. Wavelength can be used to determine the color of light since each of the color consists of difference wavelength. The type of color and its corresponding wavelength is shown in Table 2 [14]. An equation $E = hf$, where E is the energy of photons, f is the corresponding frequency and h is a Planck's constant with value 6.663*10^-34 Js is used to determine the energy of the photons with respect to their corresponding frequency. Then, the relationship between frequency and wavelength can be shown in an equation f = c / λ where c is the speed of light with a value of 3 x 10^8 ms and λ is a wavelength of the light. Based on these equations, it can be concluded that the performance of solar panel can be affected by the wavelength of light. The amount of energy in a photon is small when the wavelength is long. The solar panel is respond well to some of the wavelengths based on the materials used to manufacture them. Nowadays, silicon is normally chosen as a raw material to manufacture the solar cell. Since the spectral sensitivity of silicon is higher in red than blue, thus silicon based solar panel will have higher efficiency when exposed to red light. Spectral sensitivity is referred to the spectral response which is the ratio of current generated by the solar panel to the incident on the solar cell.

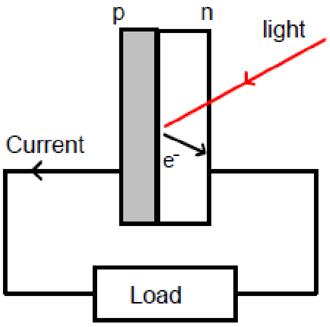


Fig. 22 - Reaction of p-n junction of solar panel when exposed to light [14]

Table 2 - Color of light with its corresponding wavelength

Color	Approximately Wavelength (nm)
White	390-780
Violet	390-455
Blue	455-495
Green	495-575
Yellow	575-600
Orange	600-625
Red	625-780

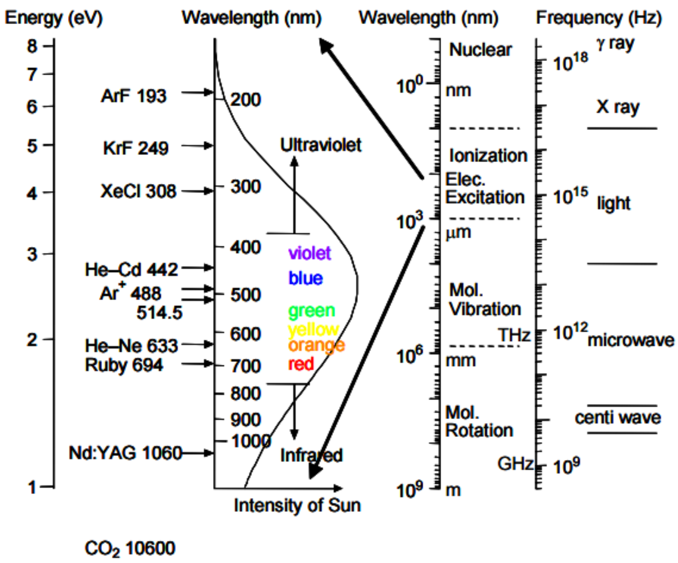


Fig. 23 - Energy Graph [15]

Figure 23 depicts the energy Graph. As stated at *Wavelength of light and energy* 2005, the shorter the wavelength, the higher the energy of the light. [15] Meanwhile, the short wavelength of light will have a high frequency as well. For example, red colour has the shortest wavelength and it has a low energy and low frequency. The relationship between energy and frequency can be represented by an equation, E = hf, Where E represents energy, h represents plank constant (6.62618x10^{-34}Js), and v represents frequency. The solar panel which has the band gap value is most recommended material to absorption light. The band gap value used to absorb light intensity is E_g = 1-2eV [16]. Silicon is the common material to develop the solar panel as it is developed with low price, non-toxicity, and indirect gap semiconductor. It has a small probability of electron move from valence to conduction group by appealing to the photon. The energy is always higher than the band gap of the solar cell. The larger is the volume of the solar cell, the higher the level of light absorbed in the same area of silicon layer. However, large volume of the solar panel will lower its efficiency due to the same area of silicon layer.

The solution to solve the problem of low efficiency is to reduce the optical damages at the interaction of light. In order to achieve this result, the reflection has to be reduced and the path distance of radiation has to be improved. Besides that, the effective light absorption can also be increased by generating the solar panel construction from a position of photo-electromotive force which only takes place when the electric field of the p-n junction transporters separate the spatial in light-generated charge. The transporters produced in the depletion area and nearby zones are separated. The separation is carried out depends on the length of the smart part of transporter diffused [17].

The voltage and current of the solar panel is determined by the temperature of the solar cell, wavelength and intensity of light. The shorter the wavelength, the higher the frequency, the higher is the energy. The reason of higher frequency that generates higher current is depended on the photon which is a basic unit of the light. It will improve its performance on ionizing atom and transferring the electron running off with higher kinetic energy if there is a high frequency of light. Thus, the electron is not being able to go back to the atom easily with this condition. Solar panel is not done well whenever there is a visible light. It only works well under the solar light which is having a wider light spectrum. The figure 24 [18] shows the graph of energy versus wavelength which proved the theory above.

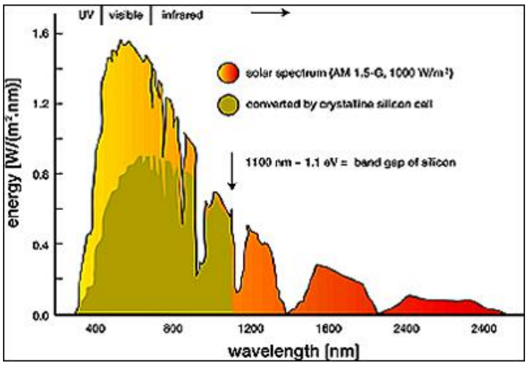


Fig. 24 - Graph of energy versus wavelength [18]

6. Methodologies

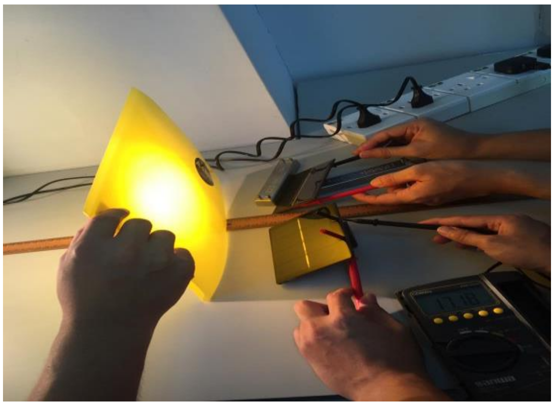
In this research, a comparison between different light sources' wavelength with two different solar panels will be carried out to test the electrical output and how well do they react to the light source in different wavelengths. Firstly, a study on the three major solar technologies – PV, CSP, and HCS will be carried out in group followed by the testing of the solar panels. Paper files with different color are used as the filter of light sources which is shown in Figure 25 (a). Testing are carried out based several color like red, orange, yellow, green, blue, and violet and the electrical output (current and voltage) are measured by multimeters. The light intensity value, distance between the filters and the solar panels, the power rating of the light bulbs, and the timing for the solar panels exposed to light source are measured and kept constant throughout the experiment. As we can see from Figure 25 (b), the light intensity is almost the same. The final results of the experiment will be evaluated in power, watts and future work will be recommended. The specifications of the solar panels are shown in Table 3.

7. Results and Discussion

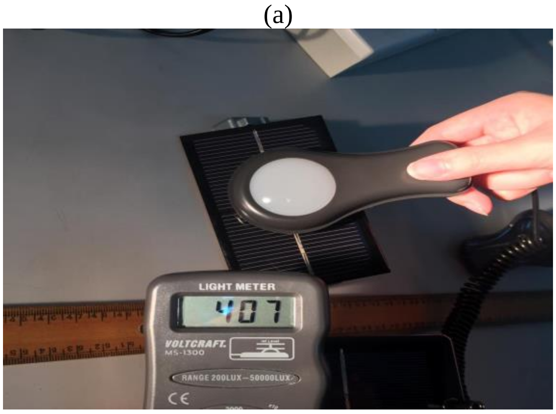
Table 4 and Table 5 show the electrical output measured by using multimeter for both Solar Panel A and B. The data in Table 4 and Table 5 are then converted into graphs which are shown in Figure 26. As we can observe from Figure 26, the voltage output of Solar Panel B is higher than the voltage output from Solar Panel A. However, the current output from Solar Panel A is higher which is shown in Figure 27. The variety of the output voltage and current is due to the differences of the specification of solar panels which is shown in Table 3. Different solar panels will react to different wavelength of light source [14].

Table 4 - Without filter of the light

Color	Approximate Wavelength (nm)	Voltage (V)		Current (mA)		Power (mW)	
		Solar Panel A	Solar Panel B	Solar Panel A	Solar Panel B	Solar Panel A	Solar Panel B
White (full sun)	390 - 780	2.207	3.080	30.525	12.13	67.37	37.36



(a)



(b)

Fig. 25 - (a) Paper files; (b) light intensity measurement

Table 3 - Solar cell's specification

Solar Panel	A (Helicentric)	B (Cytron)
Dimensions (W x H)	93 x 135 mm	74 x 120 mm
Weight (g)	90	33
Power	400mW	1W
Voltage max	2.0V	3V
Current max	0.6A	0.3A
Manufacturer	HELICENTRIC	CYTRON
Material	Polycrystalline	Polycrystalline
Type	Dip Glue	Dip Glue

Table 5 - With filter of the light

Color	Approximate Wavelength (nm)	Voltage (V)		Current (mA)		Power (mW)	
		Solar Panel A	Solar Panel B	Solar Panel A	Solar Panel B	Solar Panel A	Solar Panel B
Violet	390 – 455	1.953	2.782	21.54	8.26	42.07	22.98
Blue	455 – 495	1.950	2.700	17.20	6.64	33.54	17.93
Green	495 – 575	1.910	2.750	15.52	6.51	29.64	17.90
Yellow	575 – 600	1.932	2.600	17.18	7.14	33.19	18.56
Orange	600 – 625	2.040	2.878	24.68	10.31	50.35	29.67
Red	625 – 780	1.987	2.930	29.02	10.90	57.66	31.97

In this experiment, both solar panels are found to be more sensitive to red light, then orange, yellow followed by violet. Although violet has the highest energy due to its high frequency [14], but the solar panels do not react much on violet. Hence, the output power is slightly lower. Researchers are still finding methods to enhance the performance of the solar panel in different wavelength of light source. Energy generation from solar [19-32], wind [33-36], and biomass [37-43] have advantages and disadvantages. Similarly, Hydropower has pros and cons [44-46]. The proper way of energy distribution and considering economic and environmental impact may mitigate the drawbacks [47-52].

Moreover, people can use less energy through green buildings [53-55]. However, saving energy through a solar shower room would be a good step.

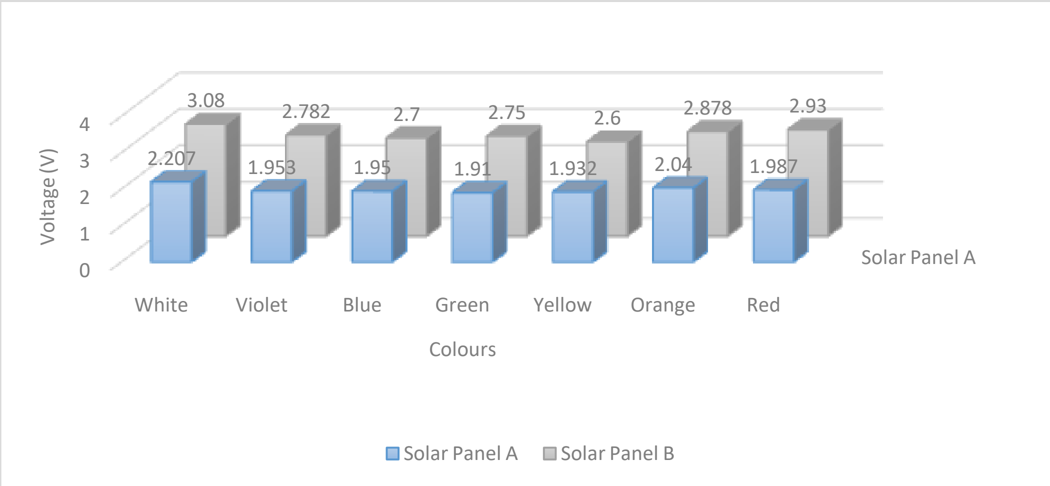


Fig. 26 - Voltage comparison between solar panel A and solar panel B

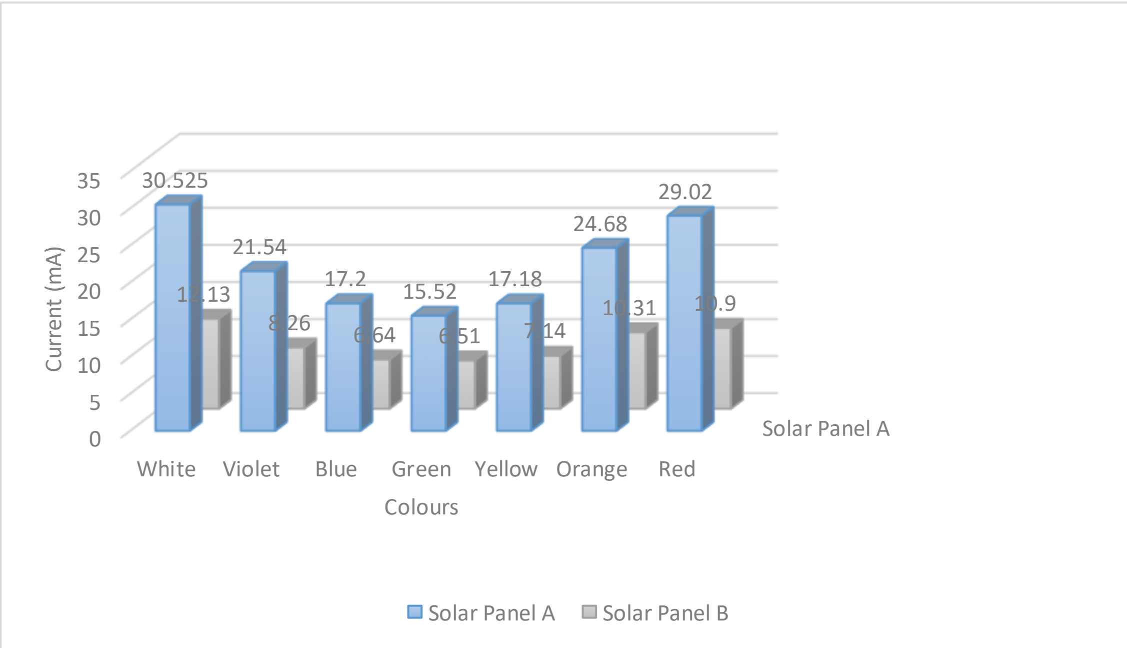


Fig. 27- Current comparison between solar panel A and solar panel B

8. Conclusion

In this research report, a study on the PV, CSP, and HCS has been carried out. These are the three widely used solar technologies in the world today with different characteristic and uses. Solar PV converts the solar energy into electricity directly, CSP uses reflective materials like mirrors and lenses to concentrate the sun's light energy and convert it into high-temperature heat, and HCS can be used as cooling system and generates heat. The generated heat energy will then create steam to drive the steam turbine that generates electrical power. In the research, the comparison between the adjacent type A and B and the wavelength of the light has been carried out. As a result, both solar cells tend to react sensitively on red lights which have the longest wavelength and then orange, yellow followed by violet. The highest value outputs by the solar cells are 57.55mW and 31.97mW respectively. The results clearly indicates that the output of the solar panel is dependent on the type of the solar panel, wavelength of the light or the color the light. Also, it can be concluded that higher frequencies will not always provide higher power output as the results shows that violet color light provides slightly lower power output value comparing to the red color though it is having higher frequencies. This research will be basement for future studies which will seek the possibilities to improve the efficiency or performance of the solar panels considering the different wavelength of light source.

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