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Solar Energy Overview

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Abstract: **Solar energy technology has developed rapidly in the last few decades. In this paper we have an overview of the solar energy technologies in various aspects. Solar energy has many environmental, economical and societal benefits. However, there are predictors for its geographical distribution, which are explained in this paper. Solar energy technologies have few types from which: Thermal, Photovoltaic and Hybrid photovoltaic-thermal (PVT) systems; using a hybrid solar system can increase the output efficiency. Photovoltaic-thermal system can increase the power capacity of the photovoltaic between 2% and 15% and increase the power generation efficiency between 2.29% and 3.37% and the PVT overall system energy between 37% and 59%. In addition, the combination PVT system can increase the life of the photovoltaic cells used in the systems. We also discussed the potentials and limitations of using the solar power in general and the PVT in particular. We have included a method for calculating the output power of the PV systems.**

Keywords: **photovoltaic-thermal (PVT), Solar energy.**

1. INTRODUCTION

1.1 Background:

Energy resources have always been the issue since the generation of technology started; we could also say that it has been the issue since beginning of time due to the need of energy even if we were thinking of the human anatomy. However, we have been dependent on the consumable energy resources such as petroleum and coal etc. the new direction in the last decades is toward sustainable energy sources such as solar energy, wind, tidal and hydropower etc. moreover, the sustainable energy supply is infinite energy that can be utilized without affecting future generations resources. Recently, sustainable energy has been developing at a rate of more than 20% annually (Kue, M. et al., 2014). However, solar energy featuring the cleanest sustainable energy since its based on exploiting sun heat for energy. In the last decades scientists and researchers have been working on improving solar energy systems to make it available and affordable.

In Table 1 we can see a comparison in development between Photovoltaic solar energy and other types of renewable energy (Benson C. et al. 2014).

Table 1: comparison between types of renewable energy technologies showing their yearly improvement rates

Type of Renewable Energy	Yearly Improvement	
PV	9	%
Turbine	2.9	%
Batteries	3.1	%
Capacitors	21.1	%

1.2 Related Work:

Many researchers have been working on solar integrated energy system for green building (Yusef, S. et al., 2014). Also a research on greening local energy was conducted which explains the geographic distribution of household solar energy use in the United States (Zahran, S. et al., 2008). In addition a paper was published on the limits to solar thermal electricity (Trainer, T. et al., 2014). Another paper was published on how we could improve the performance in solar water heating systems (Sadhishkumar, S. et al., 2014). A different paper discussed the increase of solar thermal energy storage by using a hybrid energy storage system (Zohoor, H. et al., 2008). Also, a paper has been published on a thermal analysis of high concentration photovoltaic/thermal system (Haifei, C. et al., 2014). Another paper discussed the concentrator photovoltaic (CPVs) with the addition of water-cooling system (Kue, M. et al., 2014). Also there is a paper that has been published which discussed Photovoltaic/thermal hybrid solar technology (Chow, T. et al., 2010). A paper was also written on the subject of solar-gas systems, which has experimental data and improvement rates (Alarcon-Padilla, D. et al., 2008). Another paper was written on the solar-wind system and shows how hybrid Solar-wind systems could provide enough energy for an area with large population (Roy P. C. et al., 2010).

1.3 Paper overview:

In this paper, we will have an overview of solar systems benefits, limitations, potentials and types. In Section 2.1., we will discuss the benefits of solar energy systems and how helpful they can be in providing a sustainable infinite amount of energy. Also, in Section 2.2., we will incorporate how geography, economy and environment play a big role in predicting the future of solar system in households and will understand the limits to solar thermal electricity. Then, in Section 3.1., we will describe thermal systems type and operation. After that, in Section 3.2., we will discuss the conversion of solar energy into thermal energy and its conversion into electrical energy. Then, in Section 3.3., we will understand how water-cooling systems and water heating system work. We will also talk about the possibility of increasing solar thermal energy storage. Then we will include the result of thermal analysis of high concentration photovoltaic/thermal systems. Then, we will discuss how adding a water-cooling system can improve concentrator photovoltaic (CPUs). Also, we will discuss how photovoltaic/thermal systems can work

In Section 3.4., we have included brief data about Solar-Gas Energy technology and described it’s operation. Then, in Section 3.5., we explained the potential of Solar-Wind type of systems and what featured them from other Solar energy systems. In Section 4, we included an easy calculation of the output energy of photovoltaic. Lastly, in Section 5, we will have our summary, conclusion and Potential work.

2. GREEN BUILDING

Green buildings are environment friendly building where it utilizes solar energy as its energy source. The significance of these buildings based on unlimited energy source, which extrapolates to less utilization of fossil fuel and other types of energy sources and then leads to a less polluted environment. There are two types of green buildings: passive and active. Passive green buildings are building that are designed in a way that allows sunlight to pass through into the building, so light and heat can be acquired. However, active green buildings are the building that exploits solar energy in a way that includes mechanical parts in its system.

2.1. Benefits:

There are environmental, social and economic benefits of using sustainable energy or green technology. Environmental benefits include reducing the emission of CO2 in the environment, decreasing solid waste, reducing the use of natural resources and lowering impacts on ecosystem. Social benefits of using sustainable energy include: first, providing better health for residents of green buildings; second, improving overall life quality of residents of green buildings by improving their comfort, satisfaction and well being due to some of the pros of green building like having outdoor views and having daylight inside the building etc.; third, community and societal benefits because sustainable energy interests are reducing the pollution, noise and dust which have positive effect on the ambient environment. Economic benefits of using sustainable energy include: first, reducing first cost and this can be achieved by using recycle material and also when we build a green building we would have a lot of sunlight passage and vegetation which decrease the use of heating, ventilation and air conditioning (HVAC) system; annual energy cost savings because of the reduced use of HVAC systems; and lower costs of facility maintenance and repair because the green building tend to increasing durability and mere of maintenance which decrease maintenance cost (Yusef, S. et al., 2014).

2.2. Geographic Distribution Predictors:

Geographic distribution for household solar energy depends on environmental, economical and social parameters. For example, the availability of sunlight plays an important role on the household decision of buying solar energy systems. For the less sun radiation exposure more collector cells will be needed which means more installation expenses and vice versa. Location affects the prices of solar energy units, for example, active solar energy units cost 33% more in northern United States than the southern states. Regardless, The demand of house heating is less in warmer areas and the colder area as well because in the warmer house prefer cooling over heating the houses and the colder area does not have sufficient exposure to sun radiation. Needless to say, areas that are neither hot nor cold are the optimum for solar energy technology.

For the high cost installation and maintenance makes harder for low-income household to obtain the technology which makes it easier for high-income household overcome this issue of cost. Researchers find a relation between costumer age and interest in the technology, which maximize at the age between 40 and 49. In addition to the age, the family size, age of the house occupants in general, time period and the type of educations can affect the interest of households in the solar energy technology. We obtained a statistical analysis of more than 30 counties where the data collected have proved the previously discussed detailed so we choose the highest 9 counties in regard of households using solar energy as their heating source and they are shown in Table 2 and then Figure1 shows how the number of households is not related to the number of households using solar energy technology (Zahran, S. et al., 2008).

Table 2: shows number of households in random counties and how many of them are heating with Solar Energy

	County	State	Households	Households heating with solar energy	% Solar households
1	Taos	NM	12675	360	2.84
2	Hinsdale	CO	359	10	2.79
3	Gilpin	CO	2043	38	1.86
4	Saguache	CO	2300	37	1.61
5	San Juan	CO	269	4	1.49
7	Camas	ID	396	5	1.26
8	San Miguel	CO	3015	36	1.19
9	Esmeralda	NV	455	5	1.1
10	Grant	NM	12147	1	1.07

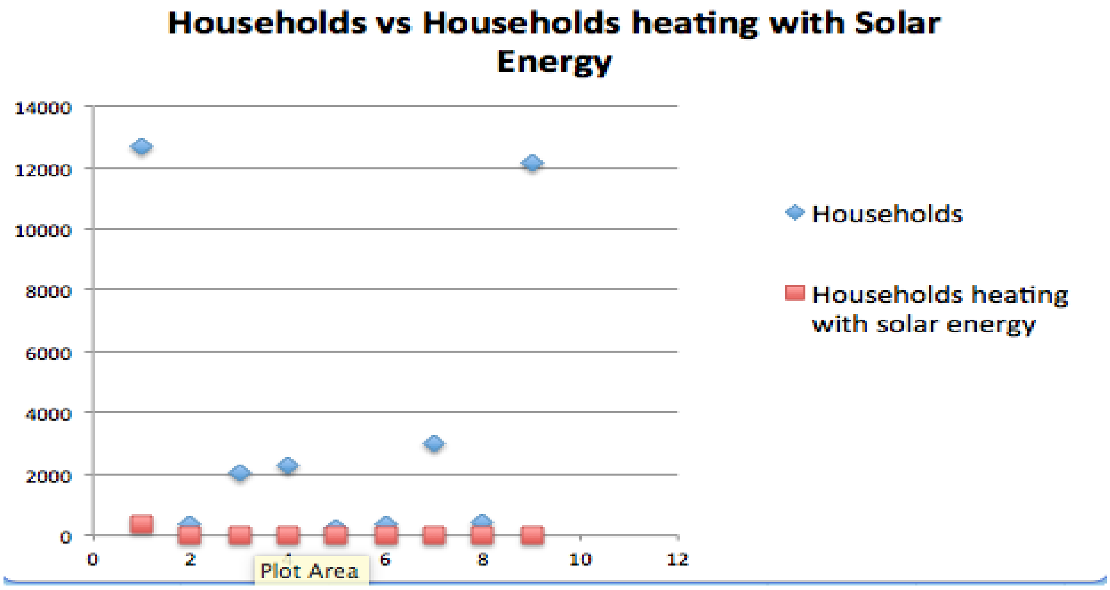

Figure 1: shows the number of households and how many of them are using solar energy as their heating source

3. SOLAR ENERGY TYPES

To understand the available solar energy technology, we have to understand the two major categories of solar energy. The first category is the solar thermal energy, which depends on the concept of converting solar energy into thermal energy. This category can be divided into two parts, passive thermal systems and active solar systems. The second category of solar energy is photovoltaic systems where this category depends on the phenomenon of converting solar light to electricity. Also there are systems that combined these two categories into one system, which can be called photovoltaic/thermal (PVT) system. The PVT technology has proven beneficial in variable aspects that will be discussed later in this paper. To widen the scope we will consider other types of solar energy technologies that uncommon compared to the previous types. We will consider the hybrid solar-gas energy technology and hybrid solar-wind energy technology.

3.1. Thermal Systems:

Converting solar power or energy into thermal energy is the one of the simplest methods that has efficiency of 70%. Comparing the efficiency to the efficiency of converting solar energy into electrical energy, which is about 17%, we can notice the large difference. The solar to thermal systems have proved easier in operation and in maintenance. So, the Passive techniques have been utilized to enhance connective thermal energy transfer. Some of these techniques are inserting twisted tapes or pipes coating etc. active thermal systems usually include pumps, venting and other mechanical parts (Sadhishkumar, S. et al., 2014). Sensible heat storage (SHS) is very commonly used as solar energy storage but Latent heat storage (LHS) is quite common as well. SHS has many types and the usage of the type depends on the need. For example we typically use water or stone for the low temperature solar energy systems. Thermal storage in sand bed is also used with moving fluid of air. In intermediate temperature concrete has been used as a medium. Moreover, for LHS particularly paraffin and salt, Phase changing material (PCM) has been used. Lately, the interest seems to be on reversible chemical reaction to be used in storing thermal energy (Zohoor, H. et al., 2008).

3.2. Photovoltaics systems:

However, photovoltaic systems have a lower efficiency and quite few limitations but we can safely say their future seems very promising. Photovoltaic system is essentially based on the concept of sunlight hitting a solar panel, which is made out of semiconducting material, creating direct current electricity. " Solar photovoltaic (PV) concentrator systems can be divided into two broad categories: point-focus systems typically utilizing square Fresnel lenses, parabolic dishes and central receivers; and line-focus systems typically utilizing linear Fresnel lenses and parabolic troughs (Tiwari, G., 2010)." PV systems can work connected to the grid or disconnected and/or work as hybrid systems. And there are three components: sun radiation, the heat and the speed of the wind.

3.3. Photovoltaics-Thermal systems:

Photovoltaic-Thermal (PVT) are systems that not only produce electricity using the PV cells but also has a part that absorbs heat and from this systems we can generate electricity and heat simultaneously. Although we desire to obtain electricity and heat from the PVT system but the main objective is to have electricity, it is important that we use the PV module at low temperature and maintain required efficiency. The requirement limits us from using the PVT system viably, so the removed thermal energy could be beneficial for the low-Temperature applications like water/air heating and ventilation. "Water cooled PV'/T systems are practical system for water heating in domestic building but their application has been limited up to now. Air-cooled PV/T systems have already been applied in building usually integrated on their inclined roofs of facades. These systems keep the electrical output at a sufficient level, covering building space heating needs during winter and ventilation needs during summer, also avoiding building overheating (Tiwari, G., 2010)."

The combining of thermal system into the PV system has other advantages than the addition of heat production in the system. The water-cooling PVT can increase the efficiency of heat conversion into electricity. The efficiency of the PV system can decrease to 8% in daylight because of the overheat effect on the PV cells. However, with the active water-cooling PVT system the heat decreased which improved the performance of the system and increased the efficiency by 13.6% (Ozgoren, M. et al., 2013).

In another study, using a concentrator photovoltaics and water-cooling system have proved effective. The results, which are shown in Table 3 and then represented in Figure 2, can show the percentage of improvement of adding water-cooling to the concentrator photovoltaics [1].

Table 3: Combination of Photovoltaic and thermal technologies Overall Percentage Improvement compared to only a photovoltaic system

	Minimum	Maximum
Power capacity of photovoltaic	2	15
Power generation efficiency	2.29	3.37
PVT overall system energy	37	59

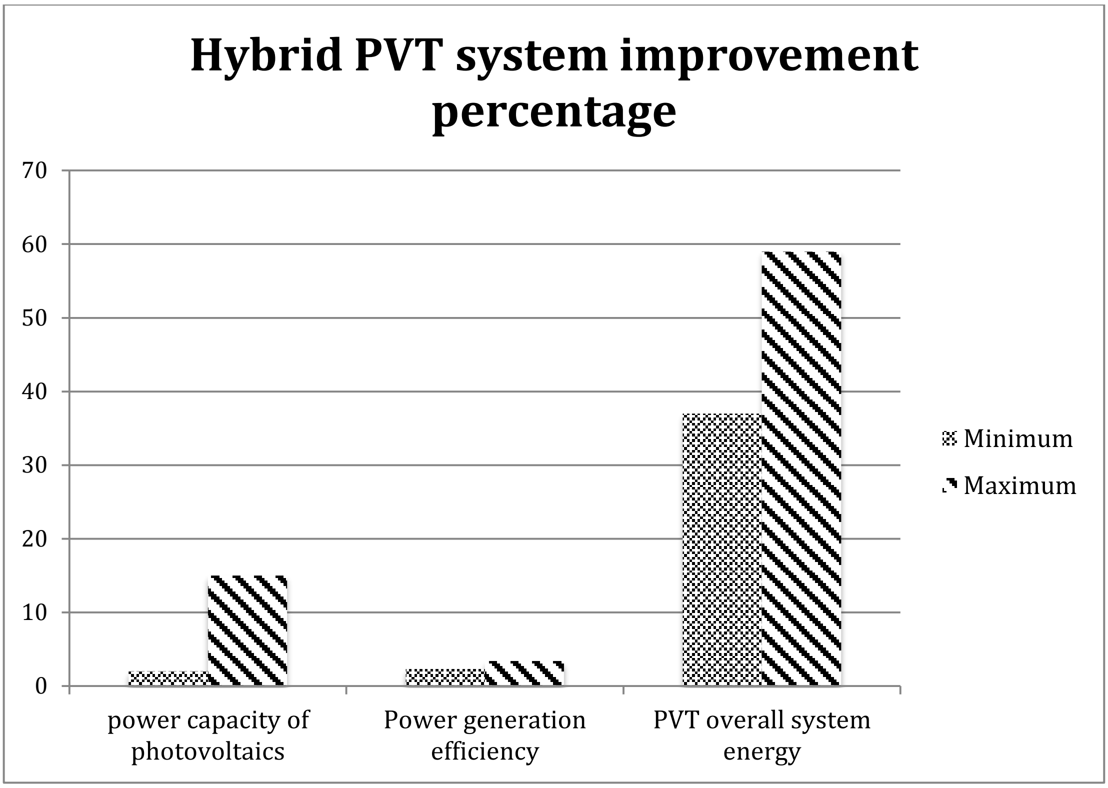

Figure 1: The graph shows how using a combination of Photovoltaic and thermal Technology can improve the overall system performance

Moreover, these Cooled PVT (CPVT) systems are fairly new and various designs and models are coming out frequently but they yet do not have a standardized test for their durability and suitability, which have been the issue for a while now. However, there are other tests that can be used and modified to layout new test standardization for these systems that output both electricity and low-level heat for domestic use. The standardized test for suitability has many parts but some of them are general and we can use them to test this new technology that include solar photovoltaic cells, such as: Internal pressure, High temperature resistance, Rain penetration, Freezing resistance, Mechanical load, Impact resistance, and Final inspection. These are some of the used test that will give us an idea on what to consider designing a new solar energy technology (Vivar, M. et al., 2011).

3.4. Solar-Gas systems:

Hybrid Solar-Gas energy technology is a fairly new technology. So, for the solar-gas systems we would have our thermal system, described in Section 3.1., collecting heat and then store the energy in a water tank. Now, we would have out back-up system, which is a gas-fired system to heat the water even more until we reach the desired water temperature degree. These types of systems are usually used in desalination where a lot of heat is required. The systems can operate in three modes: Gas only, Solar only and Dual Hybrid Solar-Gas mode. Also, we could use the system in partial division such as depending on the solar part for energy 75% and use the gas system to complete the remaining 25%. The Hybrid Solar-Gas system showed 48% in the overall efficiency while the theoretical value is 54%; the unexplained 6% difference is currently being researched but no reasoning found yet (Alarcon-Padilla, D. et al., 2008).

3.5. Solar-Wind systems:

Each type of solar energy technologies has its own features and sometimes drawbacks. For the Solar Wind systems it has a very beneficial feature, which is 24 hours energy, supply because the wind system in our hybrid system will provide energy in the absence of sunlight. So, using Solar-Wind systems depending on the exposure to sun light in any particular area and its potential wind energy we will vary our dependence on one part of the system over the other. Also, during summer season we tend to favor solar energy because generally wind is slower during summer days. And, we tend to favor wind energy during winter season because of lack of sunlight exposure and the wind is faster. So each part of the system makes up for the other which make Solar-Wind energy technology a promising technology (Roy P. C. et al., 2010).

4. OUTPUT POWER OF PHOTOVOLTAIC

For the purpose of understanding how much power we can obtain from a solar panel we wanted include in this easy calculating method. We need to know what is the average power demand then we can calculate the number of PV module and converter capacity using Equation 1, Equation 2 and Equation 3.

DED, Daily energy demand

η, *Efficiency*

V_{batt}, *Battery voltage*

C, capacity

N, number of unit

H, average daily sunshine duration hours

Loss, loss of power

$$N_{module} = \left(\frac{DED}{\eta_{system} \times Module\ Power \times H}\right) \qquad \text{Equation 1}$$

$$N_{batt} = \left(\frac{DED}{\eta_{Batt} \times V_{batt} \times C_{batt}}\right) \qquad \text{Equation 2}$$

$$C_{Converter} = \left(\frac{DED}{\eta_{Converter} \times H}\right) \qquad \text{Equation 3}$$

After, we calculate the power loss. The systems converter has a loss of 10%. Pollution can increase the power loss as well

$$\sum Loss = (C_{Converter} \times 0.1) + (Panel\ Power \times Pollution\ Loss \times N_{module}) \qquad \text{Equation 4}$$

So, as we can see that calculation of the output power of solar panel depends on the quality and the efficiency of the systems. Then, there are other factors like pollution that can affect the output power negatively (Yilmaz, E., 2009).

5. CONCLUSION

To summarize this paper, we have discussed how solar energy is an advancing technology that has a promising future. The main advantages of solar energy are that it is unlimited power and free for all. We have mentioned the benefits of solar energy, the environmental, economical and the societal. Then, we have explained the geographical distribution predictors for household solar energy technology. After that, we have explained the types of solar energy technology, which include photovoltaics, thermal, and PVT systems and explained their features and operation. At the end, we added a method of calculation for the output power of PV solar panels.

Potential future work includes enhancing the available PVT systems by trying different material for the thermal energy storage such as PCM. Also, we can research the Idea of transparent photovoltaic cells that can be used for houses windows. However, in the solar energy technologies scientists and researchers have looked into so many aspects to improve the solar energy technology and making it very efficient and relatively cheap. Most of the approaches were on the hybrid systems but their focus was on PVT and Solar-Wind energy over others, although there are other types that have not been thoroughly researched such as hybrid solar-biomass systems, solar-turbine systems and solar-gas systems.

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