FACTORS AFFECTING SOLAR POWER PRODUCTION EFFICIENCY

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ABSTRACT

Solar energy has been used for millions of years before the invention of solar panels. Many forms of life use sunlight to survive and thrive. The forms of life that use sunlight include humans for warmth and recently started using the energy of the sun to produce electricity that is renewable and sustainable. Using solar panels, solar energy is converted into electrical energy that can power an entire building. The power production from three different solar panel mountings, fixed, tracking, and adjustable, will depend on several identified factors, namely: cloud cover, sun intensity, relative humidity, and heat buildup. Netlogo program is utilized in this project to simulate the production of solar power from twenty four solar panels within an average of twelve daylight hours. The identified factors are controlled using sliders during several trials. The results of this study have been analyzed and discussed, a conclusion has been made, and a recommendation for future study is included.

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1.BACKGROUND AND RESEARCH

1.1 The Science Behind Solar Panels

The sun beams more than enough energy onto the earth to meet the needs of global energy demand for a whole year. Solar panels produce energy less than a tenth of one percent of the entire global energy demand. The panels are called photovoltaic cells which are found on things like spacecraft, rooftops, and calculators. The cells are made of semiconductor materials like those found in computer chips. When sunlight hits the cells, it knocks the electrons loose from their atoms. The electrons generate electricity as they flow through the cell.

A solar panel can generate power with a four-piece battery system that can be filled with unfiltered water, and the battery can recycle water to generate battery or power. If three panels are put together, these can produce enough electrical energy to power a home with a family of four to eight people living within the structure it is powering. It also allows a vehicle to run on solar power. In addition, a typical solar panel produces 200 watts of power or more. To power a building like a bank, for example, a five kilowatt-hour array, which is about 25 solar panels, is necessary. The solar panels will absorb 1,000 watts of sunlight per square meter on the panels' surfaces. To power a high school building, a 6.25 megawatt capacity, equivalent to 24 solar panels, is needed.

1.2 Advantages and Disadvantages of Solar Power

According to research, the sun is now halfway in its lifetime. It is predicted to consume its energy in another 4.5 billion years which is still way beyond a normal person's lifetime, thus making the sunlight a renewable source of energy. This form of energy is reliable and sustainable; it will not run out for a very long time. Using solar panels to produce electrical power is ecosystem friendly; they do not emit greenhouse gases that can increase the warming of the Earth that have been studied to be the main cause of the drastic climate changes. In the long run of using solar panels to produce power, people who go solar will save thousands of dollars since the sun will keep on providing energy that is more than enough throughout their lifetime. Finally, utilizing solar power can save people from fossil fuel dependence. Fossil fuels are not only nonrenewable but are also the main source of carbon dioxide emissions, the primary greenhouse gas in the atmosphere.

Using solar panels has its downfall such as when the weather is cloudy, it makes the technology unreliable. Also, the cost and placement of the solar panels can be very high mostly because the solar panels require a very large area that has a significant amount of sunlight to give energy to a lot of people.

1.3 Types of Solar Panel Mountings

Research shows that there are three types of solar panel mountings. These are fixed, adjustable, and tracking. The fixed solar panel mounting system is completely stationary. This is the simplest and cheapest type of solar panel. The solar panels are installed in such a way that they are always facing the equator (due south in the northern hemisphere). The angle of inclination favors the winter sun and favors the summer sun slightly less (Peak Solar LLC, 2013).

FIGURE 1. *Fixed Solar Panel Mount*

The adjustable solar panel mounting system includes adjusting the angle of inclination of the solar panel mount two or more times a year to account for the lower angle of the sun in the winter season. This system is more expensive than the fixed mount but it increases the solar panel power output by approximately 25%, thus making it more efficient.

FIGURE 2. *Adjustable Solar Panel Mount*

The tracking solar panel mounting system is the most expensive of the three types of mounting. It tracks and follows the path of the sun (east to west) during the day as well as the seasonal declination movement of the sun. The tracking solar panel output increases by approximately 25% - 30%. It cannot be denied that this type of mounting is the most efficient in producing the greatest amount of solar power.

FIGURE 3. *Tracking Solar Panel Mount*

1.4 Factors that Affect Solar Power Production

There is no such thing as a perfect technology. Research reveals the different factors that can affect the efficiency of solar panel mounting systems. Some of these factors have been studied to either increase or decrease the power production from the three types of mountings such as sun intensity, cloud cover, relative humidity, and heat buildup. When the sun is in its peak (intense), during midday, the most solar energy is collected; therefore, there is an increase in the power output. Cloudy days contribute to the decrease in sunlight collection effectiveness since clouds reflect some of the sun's rays and limit the amount of sun absorption by the panels. During summer days when the temperature is at its highest and heat is built up quickly, the solar power output is reduced by 10% to 25% for the reason that too much heat increases the conductivity of semiconductor making the charges balance and reducing the magnitude of the electric field. In addition, if humidity penetrates into the solar panel frame, this can reduce the panel's performance producing less amount of power and worse can permanently deteriorate the performance of the modules.

2.EXPERIMENTAL PROCEDURE

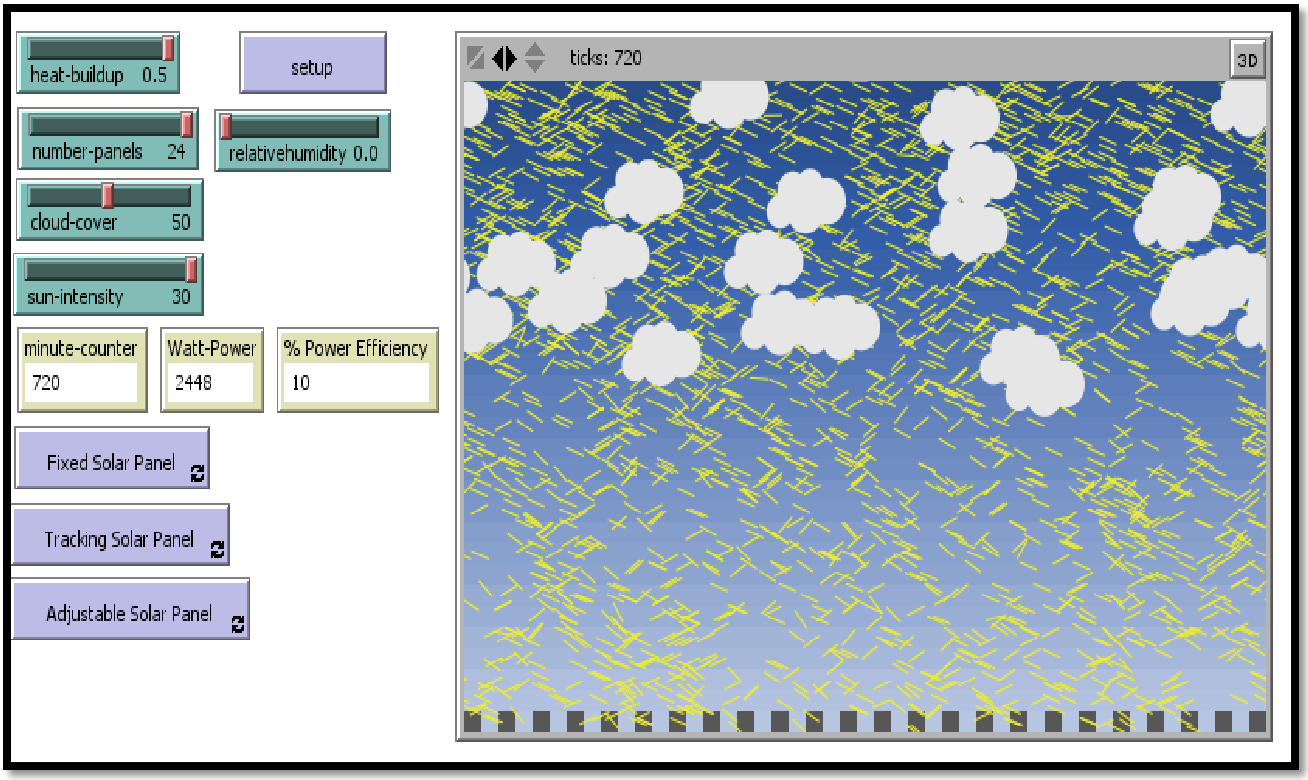
2.1 Based on Research Mathematical Calculation

According to the United States National Aeronautics and Space Administration (NASA), the approaching100% solar energy to Earth is equivalent to the solar constant of 1,353 watts per square meter. About 34% of this energy is reflected off clouds, dust particles, and the Earth. The best solar energy input being recorded (during high noon and cloudless sky) is around 1,070 watts per square meter. However, on the average, only around 893 watts per square meter reach Earth. Some reference sources use 893 divided by 4 which equals around 223 watts per square meter as the average value per hour. For every sunny day, the average power per 1 square meter of photovoltaic cell is 223 * 24 = 5, 300. All solar heating equipment lose so much heat which reduces the solar panels' efficiency to produce power. For photovoltaic panels, the efficiency of converting solar energy to electricity is around 7%. A square-meter panel array, composed of about 60-90 solar cells, will generate (5,300 * 0.07) between 370-375 watt-hours for an entire sunny day which is about 12 hours average.

2.2 Mathematical Model

Our model focuses on the effect of four factors, namely: cloud cover, sun intensity, relative humidity, and heat buildup on the efficiency of each type of solar panel mounting (fixed, tracking, or adjustable) to produce the greatest amount of power within an average of 12 daylight hours a day. The number of solar panels remains constant at 24 while we manipulate, using different sliders, the value of each of the four factors being tested. To calculate for the efficiency of each type of solar mountings, we used the formula: [power generated by the panels / the peak power generated according to research (which is 1000 watts) * area of each solar panel (which is 1 square meter) * total number of solar panels (which is 24)] * 100 or (power / 24,000) * 100.

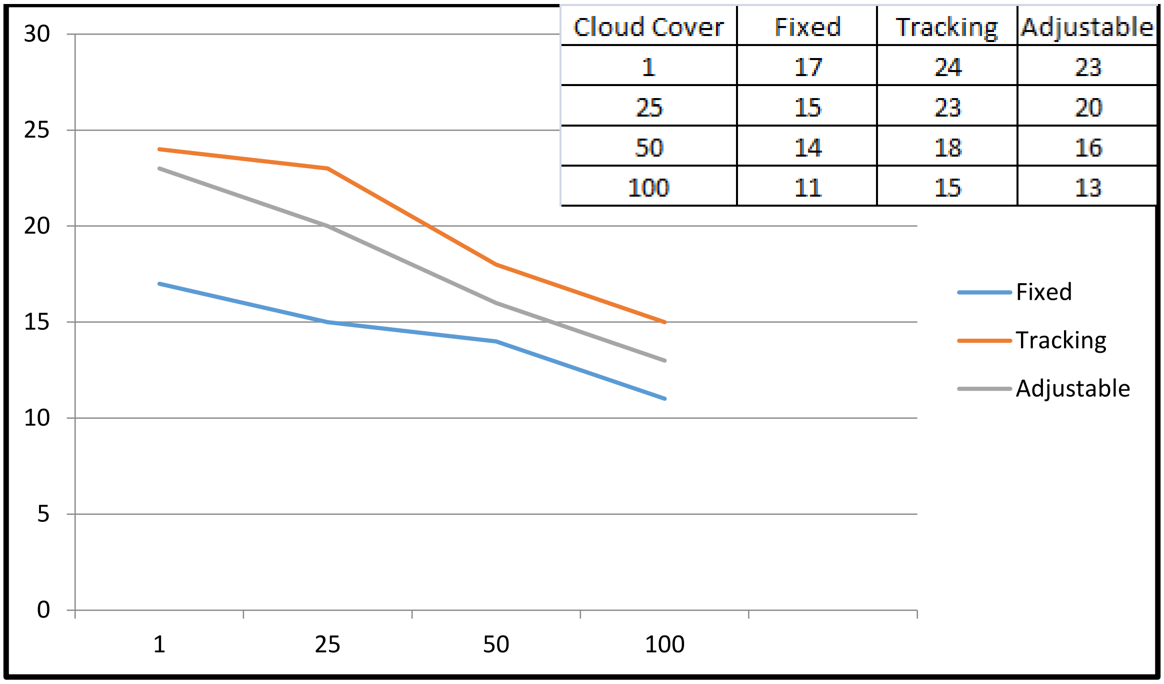
FIGURE 4. *Netlogo Interface Showing Solar Power Production with Cloud Cover*



3. RESULTS

The Netlogo model was programmed to collect data on the solar power production efficiency of the fixed, tracking, and adjustable solar panel mountings, based on the effect of the identified factors (cloud cover, sun intensity, heat buildup, and relative humidity. While studying each factor, everything else was held constant. For instance, while studying the effect of sun intensity, cloud cover was held constant at value 1, relative humidity and heat buildup at 0, and the number of solar panels at 24. When studying the effects of cloud cover, relative humidity, and heat buildup, the sun intensity was held constant at 30 and the number of panels remained at 24.

Data Table 1. *Cloud Cover vs. Solar Power Production Efficiency*

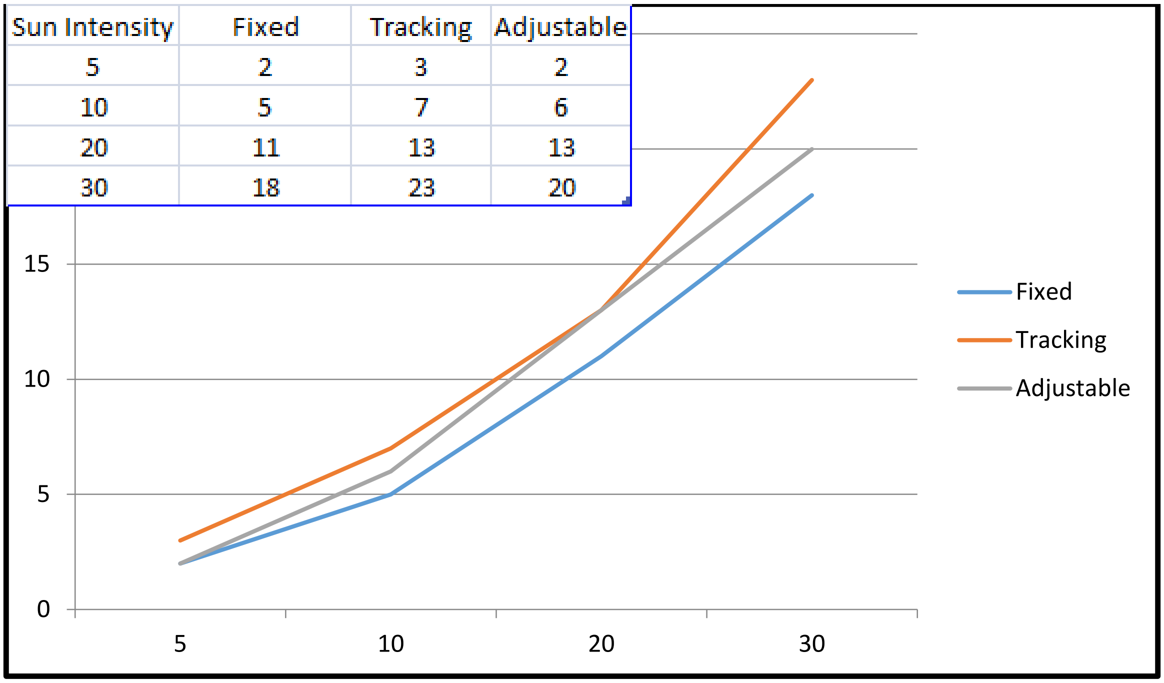


Cloud Cover	Fixed	Tracking	Adjustable
1	17	24	23
25	15	23	20
50	14	18	16
100	11	15	13

According to the data collected, as cloud cover increases the power production efficiency decreases for all types of solar panel mounting. The tracking solar panel appeared to be the most efficient even though it had a large decrease (about 9%) when the values of the cloud cover slider were changed. The adjustable solar panel mount had the most noted decrease (10%), a range from 3% - 4%, while fixed solar panels had the least decrease (about 6%) in efficiency.

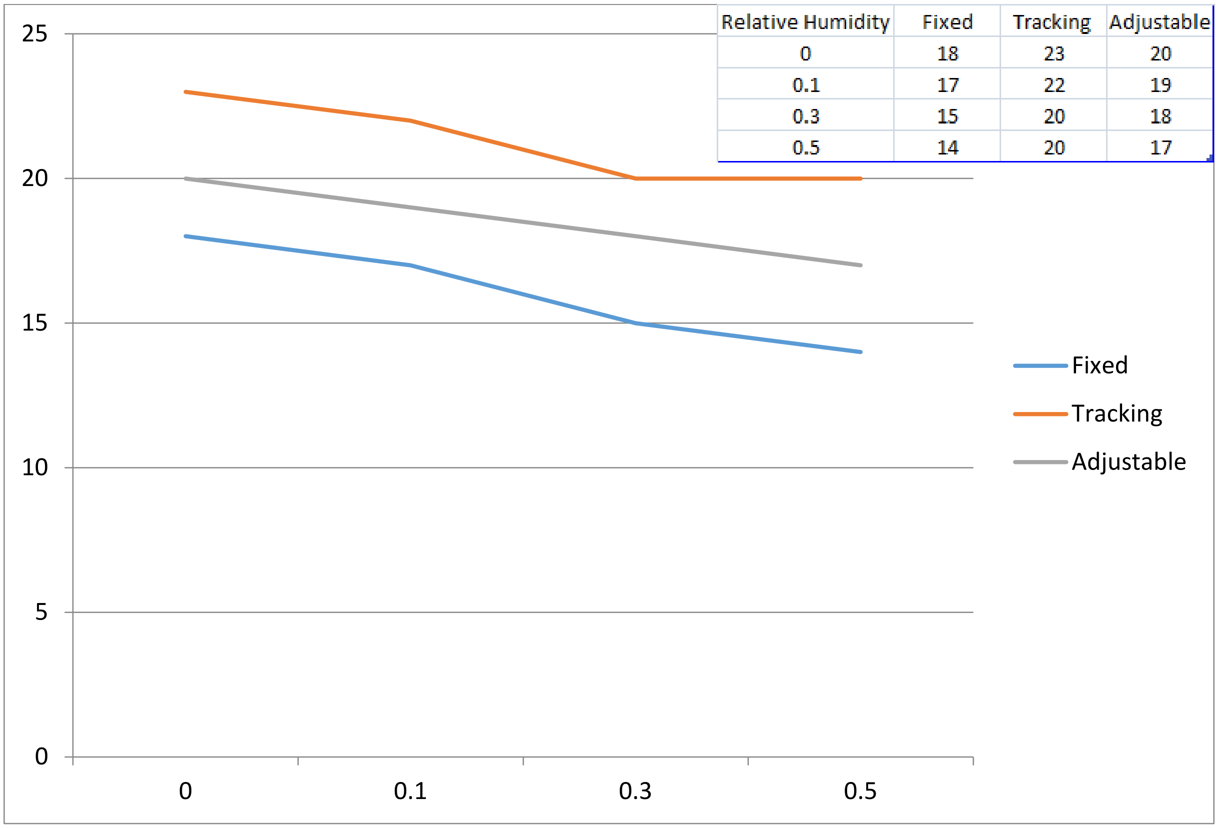
Data Table 2. *Sun Intensity vs. Solar Power Production Efficiency*

Sun Intensity	Fixed	Tracking	Adjustable
5	2	3	2
10	5	7	6
20	11	13	13
30	18	23	20



When it comes to sun intensity, the results of the data collected were based on a slider that ranged from 1 to 30, 1 being the minimum sun intensity produced and 30 being the maximum. At a maximum sun intensity of 30 the tracking solar panels were the most efficient at 23% solar power production efficiency, the adjustable were at 20%, and the fixed solar panels were at 18%. Once the sun intensity was decreased to 20, the results showed that both tracking and adjustable mounts were efficient in producing 13% of power while fixed solar panels were the least efficient at 11%. At 5% sun intensity, all three mounts showed almost the same efficiency value.

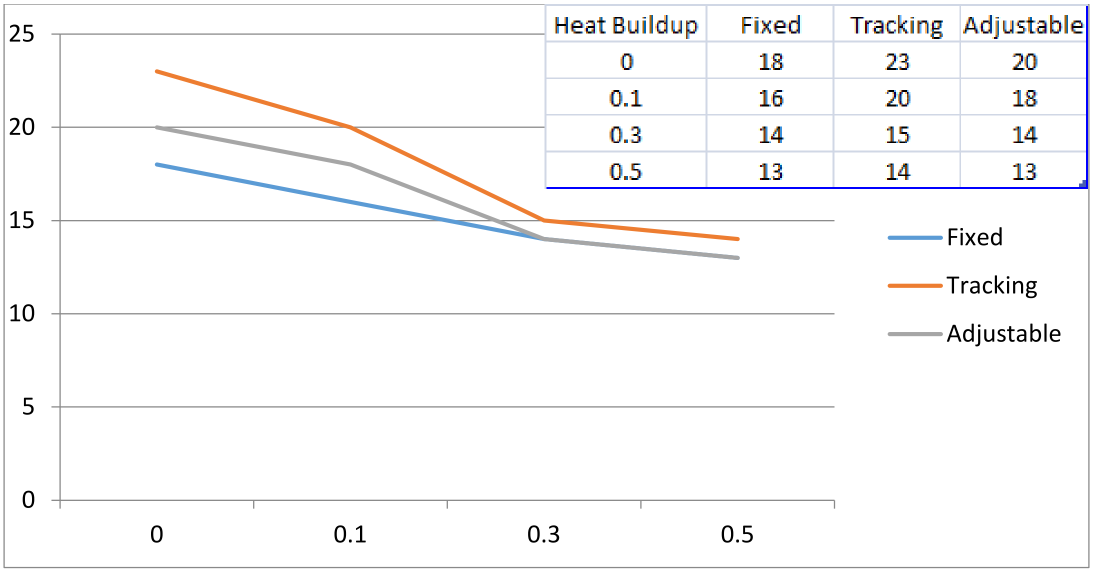
Data Table 3. *Relative Humidity vs. Solar Power Production Efficiency*



Relative Humidity	Fixed	Tracking	Adjustable
0	18	23	20
0.1	17	22	19
0.3	15	20	18
0.5	14	20	17

The relative humidity factor had the least impact on the solar power production efficiency. The tracking solar panel decreased its efficiency by only 1% - 2% and did no longer show any decrease when relative humidity value was further increased. The adjustable panel mount decreased its efficiency at a constant value of 1%, while the fixed solar panels produced the least amount of power out of the three. Tracking solar panels still produced the most power and therefore the most efficient regardless of whether the relative humidity values are increased or decreased.

Data Table 4. *Heat Buildup vs. Solar Power Production Efficiency*



Heat Buildup	Fixed	Tracking	Adjustable
0	18	23	20
0.1	16	20	18
0.3	14	15	14
0.5	13	14	13

With no heat buildup the power production efficiency for the fixed panels was 18%, 23% for tracking, and the adjustable was at 20%. But with maximum heat buildup, the fixed solar panels had shown the least efficiency decrease of 5%, the tracking had the most decrease of 9%, and the adjustable panel's efficiency was decreased by 7%. This only shows that heat buildup has significant effect on the efficiency of all three solar panel mountings to produce power. The tracking mount still produced the greatest amount of power among the three.

According to the collected data, overall, tracking solar panels are the most efficient in producing the greatest amount of power. But according to research, tracking solar panel mounting is the most expensive to purchase, install, maintain, and fixed. Therefore, when purchasing and installing solar panels, the cost efficiency of the solar panels has to be taken into consideration before making a decision of going solar.

4. DATA ANALYSIS AND DISCUSSION

Tracking solar panels are designed to track the sun rays from the time the sun rises from the east to the time it sets in the west. We strongly believe that this is the main reason why this type of mount is the most efficient in collecting solar energy and producing electrical power compared with the adjustable and fixed solar panels even when increased cloud cover is present. The fixed panel mount is facing in one direction (true south) and the panels only receive most of the rays coming in from that direction. Moreover, the adjustable solar panels are more efficient in producing power than the fixed mount because the panels' angle of inclination can be adjusted two or more times a year; therefore, the panels face the sun more and absorb greater amount of solar energy.

The Netlogo model showed that as sun intensity decreases the power production efficiency of all three types of solar panel mountings decreases as well which should not be a surprise since the sun's rays are the main source of energy that are converted to electrical power. When sun is less intense, especially in the mornings and in the afternoons, then the amount of absorbed solar energy is reduced producing decreased amount of power. On the other hand, when the sun is at its peak, during midday or noon time, the sun intensity is at its greatest producing increased power from the panels.

During rainy days, the relative humidity in the air is increased. This has a slight effect on the panels; as humidity penetrates into the solar panel frames, it reduces the panels' capacity to produce power more efficiently. The data showed that as the relative humidity increases, the power production efficiency of the three panels decreases. There is an inverse relationship between relative humidity and solar power production efficiency.

Heat buildup is another factor that has significant effect on solar power production. Before we did the research, my team was thinking that the hotter the day, the more power is produced but we were surprised to learn that this is not the case. Increased heat buildup produces decreased power and this is evident in the data we collected. It surprised us to know, during our observations, that tracking solar panels had the most decrease in its efficiency to produce power. We strongly believe that the reason for this large decrease was due to the mount's ability to track the path of the sun, therefore facing the sun at all times during the day, about12 daylight hours. The mount absorbs the most solar energy and since there is no perfect technology that cannot overheat, it will build up more heat than the other types of mounting and therefore reduce its ability to produce power efficiently. Although fixed and adjustable solar panels still showed a decrease in the solar production, the decrease was not as high as the tracking mount since these types do not track the sun and can only absorb less amount of radiation from the sun than the tracking type.

5. CONCLUSION/RECOMMENDATION

Using solar panels to generate electricity will replace the way we use our natural resources. Solar technology will reduce the gas emissions that are the results of burning fossil fuels such as coal (the main source of electricity within the city). This will improve the quality of our Earth's atmosphere and create a stronger ozone layer in the process. Aside from its positive effect on the surrounding, harnessing solar energy using solar panels is cost-efficient and its reliability is beyond unreasonable doubt. Solar energy is renewable which means that we can depend on it for the rest of our lives.

All identified factors, cloud cover, sun intensity, relative humidity, and heat buildup, have affected the solar power production efficiency of the three solar panel mountings. Sun intensity is directly related to the power production – as it increases, solar production increases as well. The other three factors exhibit an inverse relationship with solar power production. As the values of the three factors such as cloud cover, relative humidity, and heat buildup increase, the solar power production decreases. Out of the three types of mounting, the tracking solar panels appear to be the most efficient in producing the greatest amount of solar power but research shows that its high cost of installation and fixing makes this mounting system less efficient overall. After doing several researches for this project, our team recommends the fixed solar panel mounting as the preferable mounting system since it is the simplest and least expensive of the three mounts. Buying additional number of fixed solar panels can still provide the same amount of power that less number of tracking solar panels will produce with the same expense.

6. FUTURE RESEARCH

Our team has planned to use the results of our project to do a feasibility study on installing solar panels at our high school to supply us with enough electrical power that will reduce the cost of our school's electrical bill throughout the school year. Having the knowledge that the fixed solar panel mounting system is the most efficient cost-wise, we will recommend this to our school district as well as to our community. In order for our plan to become a reality, we plan to continue our research but this time we will include the cost of installation, layout of our school ground, and visit solar companies to solicit great ideas from them on how to go about our plan in a way that we can reduce the costs of solar panel purchase and installation. We also plan to seek financial support from the community so our school district does not have to shoulder the total expenses for this project.

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