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SCHOOL OF ARCHITECTURE, BUILDING AND DESIGN

BACHELOR IN QUANTITY SURVEYING (HONOURS)

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Lecturer: Ms Lim Tze Shwan

Building Integration of Solar Energy

Name	Student ID
Yip Xiaojung	0323852
Alwin Ng Kun Ket	0323596
Goh Jia Jun	0323302
Kenneth Tan Sin Kwang	0322482
Ng Sheng Zhe	0323830

Table Of Content

Introduction

Due to the huge consumption of energy increasing day by day, more renewable energy sources have been discovered by scientist and one of the most useful renewable energy sources is solar energy. Solar energy is a radiant energy emitted by the sun. Although the distance of sun is 90 million miles from the earth, it takes less than 10 minutes for light to reach the surface of earth. Solar energy comes in abundant as surface of the earth receives 120,000 terawatts of solar radiation which is 20,000 times more power than what is needed to supply the entire world. Moreover, solar energy can be used in every country that is able receive sunlight. Radiant light and heat from the sun is able to produce endless amount of energy to be used in daily life of the people. Although there is no sunlight at night, solar energy can be kept in storage device such as a battery so that the electricity generated can still be used at night. Solar energy can also be converted into electricity by using a solar cell known as photovoltaics.

In 1839, a French scientist by the name of Alexandre Edmond Becquerel discovered the photovoltaic effect which explains how electricity can be generated from sunlight. He claimed that “shining light on an electrode submerged in a conductive solution would create an electric current.” Over 100 years later, in 1941, Russell Ohl which is an American engineer invented the silicon solar cell, shortly after the invention of the transistor.

Earth has been surrounded by sun for billions of years, therefore the energy transmitted from the sun to the surface of earth is enormous. We should not waste this huge energy given by the sun, instead we should utilize it into our daily life. For instance, solar energy can be used to heat up water, create warm environment, charge certain devices and more. In order to gain solar energy, a solar panel needs to be installed to receive sunlight. Although the installation fee of solar panel may be expensive, it is actually worth the money spent for long term use because a solar panel can last average from 20 to 25 years. The use of solar energy reduces the amount of electricity bill because it is free. Besides, solar energy will not cause pollution and effects therefore it is environmentally friendly.Solar energy is an

alternative energy expected to replace other non-renewable energy by the future because it will be more widely available and cheaper in installation fee soon. It is also expected that more than 1 million houses in United States will be utilizing this technology by 2016. Solar energy is also used by other living things besides humans. For example, green plants use solar energy for photosynthesis to convert light energy to chemical energy.

There are 2 types of solar energy which are active and passive depending on how the solar energy are acquired and distributed. Photovoltaic panels and solar thermal collectors which harness solar energy are the examples of active solar technology. Passive solar technology includes constructing rooms to improve air circulation, orienting space to favorably use sunlight. Although a lot of countries are utilizing solar energy, the highest installed capacity of solar photovoltaic power is Germany. Although United States have more lands than Germany, Germany manages to stay top by having the highest capacity of solar photovoltaic power in the world at 32,4 GW at the end of 2012.

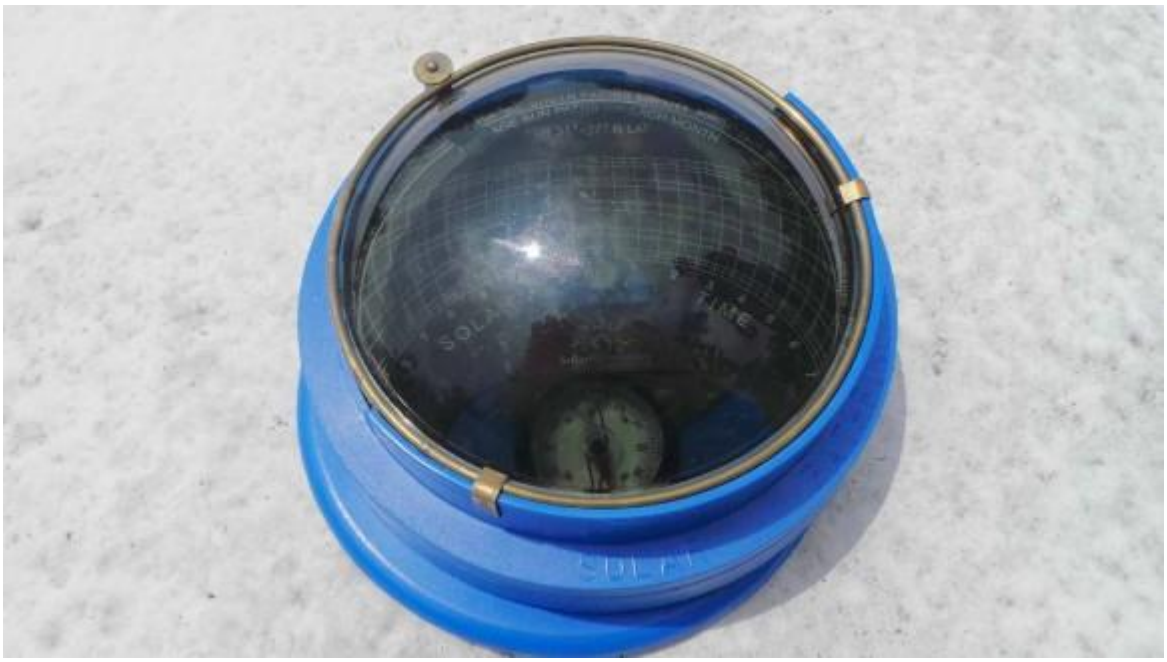
Installation Process

Evaluation

The first and foremost step of installing a solar panel system always starts with the suitability of the system. Site surveying plays an important role and allows a site engineer to correctly determine the suitability of setting up the solar panel system. There are a few aspects of the site that must be achieved before the suitability of site is determined

The first aspect that we must take into account is visibility of the sun. The optimum condition for the direction of the house is to face the south or north. This ensures the path of the sun does not face directly towards the house and cause excessive heating but on the other hand, allows enough sunlight to hit the solar panels in order to generate electricity throughout the day.

In addition to the direction of the house, it is also necessary to determine and obtain the times of the day that particular areas would be shaded.



The solar path finder as in the picture allows the surveyor to determine the correct position of the solar panels. The solar Pathfinder is set up at the 4 corners of where the solar array was going to be installed and with it point towards the south. It has a series of marks on it and a glass dome which reflects anything that would be throwing a shadow. You basically look at the reflection and see what time of day the shadow might affect that spot.

Selection

In addition to the geographical criteria, it is also necessary to ensure the roof is able to withstand the huge weight of the solar panels. Some systems may weight up to a ton but most roofs will have no problem bearing the weight as the weight is distributed over a large area.

After the site has been determined suitable, the size of solar panels systems is selected. The size and the roof and the price of the system affects the selection process therefore it is important to select the type of solar panel that meets your needs. One example is the amount of electricity it generates. If the daily consumption of your house electricity is around 8k/mph it is unreasonable to buy a solar panel that provides more than what you need.

Contract

After the final site survey and all equipment pricing has been worked out, contracts had to be signed between the local electric company as those contracts had to get sent off for approval by the electric company because in order to be tied into the grid. This will allow the resale of excess electricity back to the company and therefore you can profit from installing these systems. Sometimes, the electric company will also opt to foot part of the bill of the system, they had a bunch of rules about how efficient the systems have to be and therefore contracts were negotiated for the following reasons. Efficient management of the system also falls under these contractual obligations.

Installation of hardware

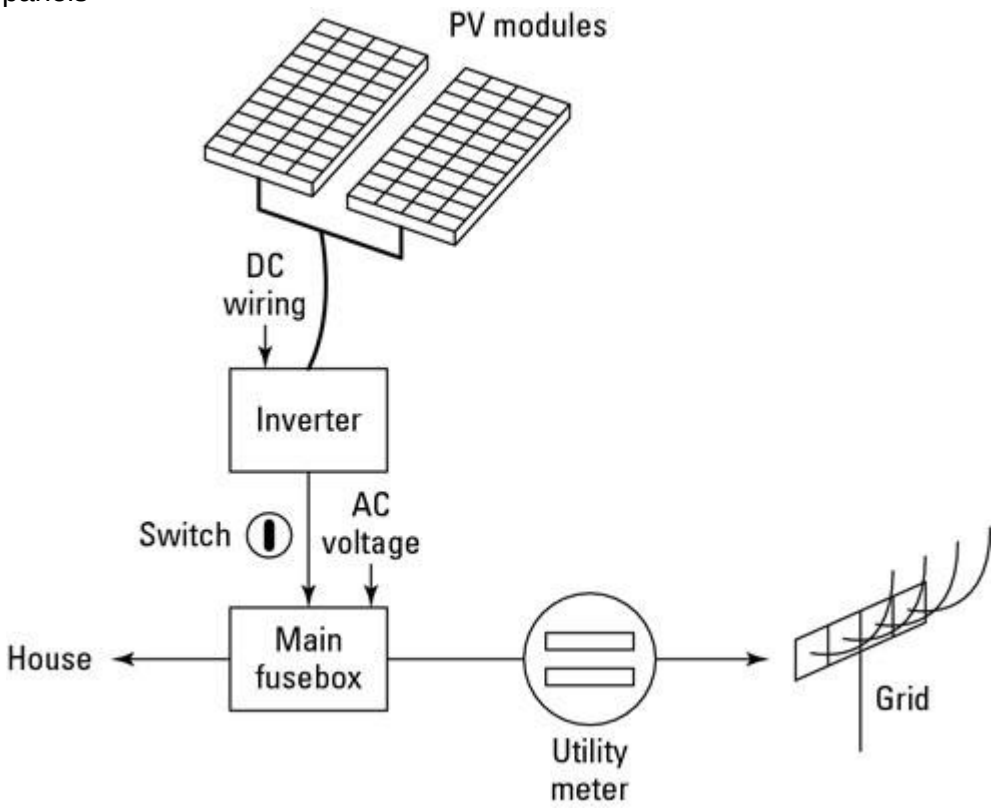
Major components in solar panel system

Solar intertie photovoltaic (PV) systems consists of multiple parts:

The most important part of the system is the solar panels which collect the sunlight and turn it into electricity. These panels are placed on mounts which hold the system intact for long period of time. More advanced mounts such as tracking mounts can mechanically move the PV panels over the course of a day so that they directly face the sun at all times.

Inverters are a main component in the solar panel system. The energy obtained from the sun is a DIrect Current, however due to the Alternating current demands of the house, The DC signals are fed into an inverter, which converts the DC into grid-compatible AC power (which is what you use in your home).

Lastly, are switch boxes and utility meter. Switch boxes allow the switching on and off of currents and are often included for safety reasons. Utility metres in the other hand provide an accurate reading for the amount of consumption and production of energy from the solar panels



Installation process of panel on mount

There are many different type of mounts that a solar panel can be placed on, they are, roof mounts, pole mounts, ground mounts and car porch mounts.

Flush (Roof) mount

Flush mount can be used for any pitch, any roof, at any time. It is one of the most easy-to-install and cost-effective mounts.System advantages includes 100% aluminum rails, which is lightweight and corrosion resistant. Flush mounts are also designed for fast and easy installation because no grounding lugs or copper wire needed! It also has a in-house engineering services which provides easy maintenance and custom options for nearly any roof type so it is a very flexible system. (schletter nd.)

Ground Mount

The Ground mount System is designed to be the most cost-competitive solution for large-scale solar mounting systems, with proprietary aluminum extrusions to reduce material usage and the highest level of in-house pre-assembly on the market. The result is an attractive solar mounting system installed quickly and with the durability to last. The advantages of a ground mount system is high level of pre-assembly for fast installations and easily accessible for ground and system maintenance. Besides that, the ground mount system also provides a larger area and weight load to rest the panels upon. (schletter nd.)

Soil conditions are the main concern in installing the ground-mounted solar panels because the typeof the ground will make the installation process very complex. On the other hand, if the soil conditions are appropriate, the installation process is much easier and thus the maintenance and cleaning process are also more convenient. (Brightergy 2013)

Pole Mount

Pole mounts are being distinguished by how the pole mounts are placed on the pole. The uppermost part of the pole mounts contained of a metal rack and rail unit that is secured to a huge sleeve that rests ahead of the pole. The mount will then simply slips over the top most of the pole, and the solar unit can be placed into place by welding the solar panels or bolting them. It is important to take into account of wind load as the pole might be less stable when compared to the flush mount and the ground mount.

Side-of-Pole Mounts are intended to grip 1 to 4 modules. The side of pole mounts is installed by mounting it to the pole with a choice of hose clamps or U-bolts. The racks acclimatize distinctively sized poles and are modified to 15-65 degree in 10 degree increments for optimal sun angle. The size of the pole is being affected by the number of modules to be mounted on. (Wholesale Solar 2014)

Mounting of Panels

Before the installation of panels, a temporary work is set up for the workers to work. Scaffolding is constructed as the optimum platform for the workers. Next, anchor bolts are screwed in to hold the system in place. The anchors are placed on top of the roof tiles on their desired position, and the measurement is being checked again to ensure that the anchor are in the right position. Frames are then attached by the anchor bolts.It is crucial to ensure the position is correct or the panel wont be able to slide in. The next process is by installing the panels. Since the bars are now in the right position, the panels are then clamped to the frame and the panels on the roof are wired to produce adequate electricity. Inverters are used to convert the Direct Current into Alternating Current before the electricity is flowed into the house for usage. -(EVO 2012)

Management

Solar panels generally require very little maintenance since there are no moving parts. A few times a year, the panels should be inspected for any dirt or debris that may collect on them. The dust and debris on the system may cause the system to reduce the intake on sunlight and generate less electricity. Therefore, general cleaning may be important to keep the system going.

The roof should also be inspected every couple of years to ensure it is still able to bear the weight of the solar panels. It is also a good idea to hire a professional service crew to help to inspect the solar panels every now and then to ensure the system functions properly. Tracking mounts may require oiling to allow smooth movement of the panels. It is important to keep the receipts of purchagn in the panels as panels usually come with a manufacturer warranty that may last a long time.

Inverters must be checked regularly for functionality as the rate of conversion may tear over time and inefficiency may occur. Regular change of the switch box also encourage a good functioning electrical system of the circuit and reduces chances of a short circuit.

Advantages of Solar Energy

1.) Renewable Energy Source

Solar energy is a truly renewable energy source as it will not be depleted when used. It can be utilized and be available all time around the world without any limitation. Solar energy will not be run out unlike other sources of energy such as petroleum and natural gas. As according to scientist, sunlight will be available for us to use for another 5 billion years from now and this energy is very reliable as the rising and settling of the sun is very consistent in our country. Although sun doesn't exist at night, it contain a storage system for the solar energy to be used during night time or rainy days.

2.) Low Maintenance Costs

Solar energy generally does not require much maintenance as compared to the used of other energy. The reason why it is low maintenance because it has no moving parts. Without moving parts, there are very less chance of crevices for debris to get stuck in. The only main concern for it the user have to keep it clean and cleaning it a couple times per year will do. The average lifespan for a solar panel lies between 20-25 years as for the inverter will be approximately around 5-10 years. Inverter is the system that convert the solar energy into electricity and also heat energy. Apart from these, solar panel also does not produce any noise which is a ideal choice for residential and commercial buildings.

3.) Diverse Applications

However, solar energy can also be used for diverse application. It can be used to generate electricity for home, building , offices and etc which is known as the photovoltaic power system or heat energy known as solar thermal normally used for heating hot water for domestic uses and also increasing the temperature of the house during winter. Other than that, solar energy can be used to produce electricity to area where there is no access to the energy grid, to distill water region where water supply is limited and to power satellites in space.

4.) Does not cause Global Warming

Solar energy is an alternative energy of natural gas, fossil fuel and many others non-renewable energy. Solar energy is non polluting as it does not pollute the environment, clean, reliable and it is also a renewable energy resources. It does not pollute the air by releasing gases such as carbon dioxide, carbon monoxide, nitrogen oxide and etc. By the use of solar energy will helps to reduce the risk of environment being damaged. Solar energy does not require any backup system such as fuel to produce electricity and heat energy. Thus, this helps to avoid the transportation of fuel and storage of radioactive waste.

5.) Easy Installation

Installation of solar panel is very easy as it does not require many wires, cord or power sources to function unlike the use of geothermal or wind energy which required wires to be tied using drilling machines. Solar panel can normally installed at the rooftop of a house or building which means the owner does not need to come out with a new space to store the panels. With the use of solar panels, each home or building can automatically generate it own electricity.

6.) Can be used in remote or rural areas

Solar energy can be a great advantage to be used in area where the area have limited access or even no access of electric power cable. The use of solar energy is used to solve the current problem of electric cable lines where running cable to the rural area would be a

difficulty and even costly. However, solar panels can be set up to receive solar energy and convert it to electricity or heating water to community as long as it receives sunlight.

7.) Reduce home electricity bills

The utilization of solar energy to create power supply to home can allow you and your family members to use without any limitation as solar energy are free and renewable. Unlike using electricity to generate power as the more consumption the more it cost. Having a solar panel at home helps to eliminate your upfront cost that you might have to pay using your own saving money. Other than that, the homeowner can also sell their surplus or extra generated electricity to the utility companies which are able to help them reduce their monthly electricity bills. Lastly, using solar energy offer cheaper annual cost as compare to electricity.

Disadvantages of Solar Energy

1.) Initial cost of the Solar Panel is expensive

Although using solar energy is economical due to it lower long term cost, the first disadvantages of using solar energy is that the initial costs of the solar panel and the installation fee are is bit higher than other alternative energy depending the size of the solar panel. The main reason why the initial cost is high is due to the part are expensive such as the inverter, batteries and etc.

2.) Location and the availability of Sunlight

The second disadvantages of using solar energy is that the location of the solar panel is the major importance for it to generate electricity or generate heat. It is normally located on top of the roof and for housing that are covered by tree, landscapes or are covered by huge buildings at the surrounding are not suitable for the installation of solar panel. Although it may still able to function if installed at this area, it will reduced the rate or maybe require more panels to be installed in order to generate sufficient electricity to home or offices.

3.) Installation Area

For normal house users, solar panels are normally installed at their roof top as home does not require huge amount of energy which mean that less solar panels are needed. While for

huge buildings or big industrial, a larger area may be required for the installation of solar panel in order to provide sufficient electricity to the buildings on constant basis. Solar panel are being seen installed on the ground but this method is considered not a good choice as the panel may caused obstruction to the users or public.

4.) The Reliability

With the use of other alternative energy such as geothermal energy can be used during day and night without any limitation. However with the use of solar energy, one of the disadvantages is it poor reliability of solar panel. Solar panels had been proved to be useless as it rely mainly of the local grid utility to generate power or by the use of solar batteries for storage to store the excess power so that it is able to utilize at night or when during cloudy days.

5.) Polluted environment can caused damages to the solar panels

Most of the photovoltaic panels are made out of mercury, cadmium, lead and other toxic material such as silicon are easily being damaged by pollution in the environment. As this will reduce the efficiency and quality of the photovoltaic cell. Lastly, this also reduce the lifespan of the solar panel.

CASE STUDY
Elithis Tower - Dijon, France

Elithis Tower, located in Dijon, France is one of the first energy positive building. It first opened in 2009. This means that it produces more power than it uses. It houses over 330 solar panels on the rooftop.

It consists of 10 floors which houses:

a) 4 levels of – Elithis Engineering
b) Ademe (Departmental Agency of Energy Management)
c) Radiological services
d) Restaurant
e) Civil Engineering offices
f) 1 technical level of HVAC system (Heating, ventilation & air conditioning)

It was a demonstration & experimental building. It is considered an experiment as many research & development were put into the design and construction of this building. Many methods of energy conservation and production were used as to create this energy positive building.

The energy production of the building is proudly advertised in the board of the building for the public to see.

The main objective of this unique building is to use natural and passive ways such as the Sun (Solar Energy) & wood (from trees) to achieve a visually appealing and comfortable

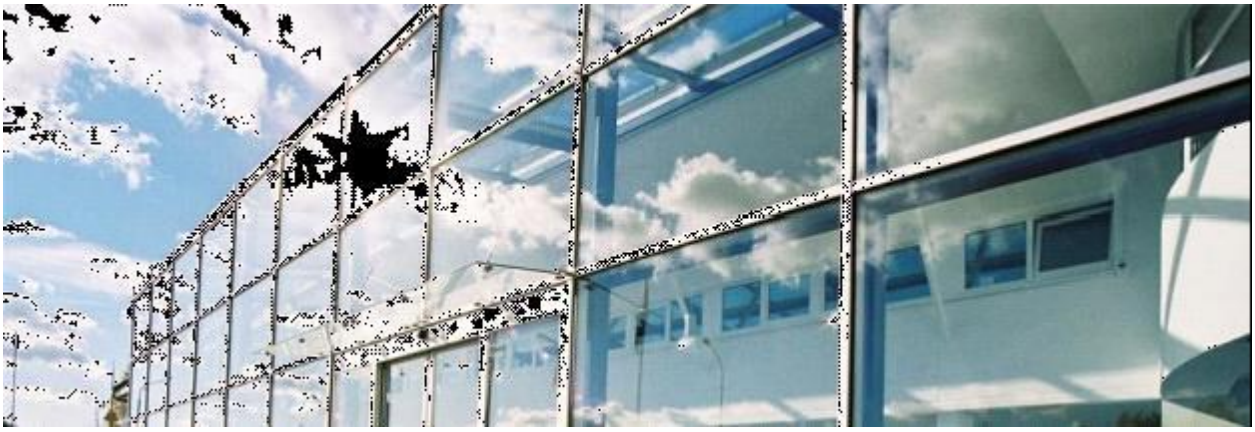
design. The other objective is to study different design methods which can help with reducing energy usage.

The cost of building this energy positive building is comparable to office buildings of the same nature at roughly $10 million. This building is 54,000 sq ft with over 10 storeys. Considering its energy producing qualities, it is a very sustainable building and is also relatively cheap to construct.

The design of this building is very compact. It is located in the city. The materials used in this building is very economically friendly as it uses recycled materials like wood, cellulous wadding & bay windows. High environmental impact materials like aluminum were used stingily. The bay windows are used to help with extracting the lighting from the sun and negating the detriments like glare, UV & overheating. The bay windows comprise of double-glaze and filled with argon which helps with thermal insulation.

Double-Glazed Bay Windows

Cellulose Wadding
Aluminum



Lighting

In this mostly glass panel covered building, natural lighting is used. The increased rate of glass panels drastically reduces energy needed for artificial lighting. The passive solar shield helps reduce excess heat and protecting the users of the building from receiving direct sunlight. The direct sunlight can contain harmful rays which can harm the users and are very dangerous especially in long periods of time. It provides great natural lighting for office users. If lighting is required when natural sunlight is unavailable, the light fittings in the ceiling provide for it. It is coupled with motion and light sensors when needed. This can help especially during cloudy days, night time and rainy seasons. The installed lighting power is rated at ~ 2W/m² of electrical energy. If high illumination is required, *Nomadic Lamps* are used. These are all controlled by the BEM system

Nomadic Lamps

Solar Shield *Conventional Lighting*

By using the solar shield, the building can cut electric usage drastically as there will be no need for conventional lighting methods.

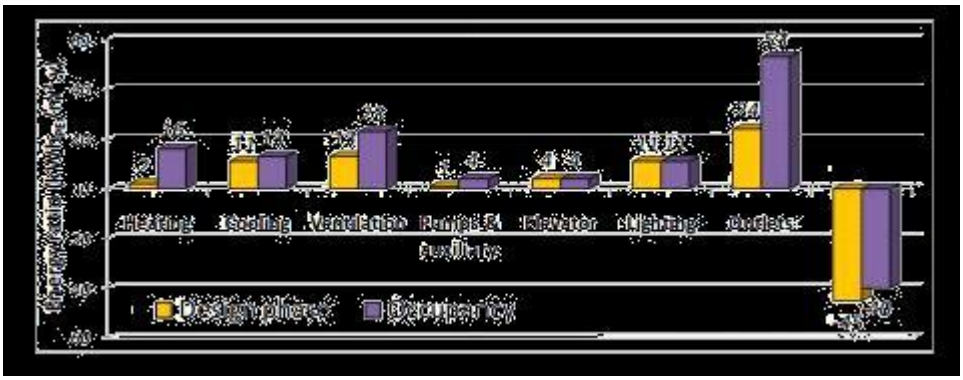
Heating & Cooling

The majority of the heating of the building is covered by natural heating (solar) & internal heat gains. For backup purposes, one low-power wood boiler provides the heat which provides for thermal comfort. There is another wood boiler which are used as a backup for the first low-power wood boiler. This system is used as it helps maintain 21°C of room temperature throughout the building.

Energy Performance

The concept of this tower is to balance the electricity use with the *Photovoltaic (PV)* roof panels. The PV panels generate electricity. The PV panels has a low ratio of installed PV panels compared to the floor area. The minimal energy usage of the building is supported by the 500m² PV panels. It is built with a horizontal incline as to maximize the generation of electricity. The building is constantly monitored by over 1600 sensors all over the building.

This helps the team inside the building to constantly do reports of the building energy performance.



Energy consumption of production of the building.

Solar Panels – horizontally tilted

Solar powered buildings examples:

Heliotrope in Germany

It is one of the first zero-energy modern homes which produces over 5 times the energy it consumes.

Sonnenschiff – Solar City

This solar city can produce up to 4 times the energy it consumes. It emphasize on using solar panels right before the construction starts, compared to solar panels being an after-thought.

Dragon-Shaped Solar Stadium – Taiwan

Comprising of 8,844 solar panels, this solar stadium can seat up to 50,000 people and generate 100% of its energy used.

Activhaus B10 – Stuttgard

This green house creates enough power to light up 2 houses & 2 electric cars. It uses a photovoltaic system that produces over 8,300 kWh per year.

Gigafactory – Tesla

This “Gigafactory” is currently undergoing construction and when completed, can produce battery cells. When fully completed (estimated 2018), it will reach full capacity and will produce more lithium ion batteries. It is powered by *photovoltaic* panels.

These various projects are very similar to the case study above. These projects usually produce enough energy for powering itself and in some cases, produce more than required.

Conclusion:

From this case study, it can be seen that solar-powered buildings are constantly blooming and are very sustainable. It can help reduce energy usage to very low – close to zero. This is very good news as it can help with our pollution problems and can help lengthen the planets lifespan.

The futuristic & modern design is visually appealing and also serve as a function. From the case study above, it shows that the design of the building can highly impact the energy usage & production of the building. (ie; solar shading, building envelope & etc.)

I believe that with further research and development, more energy-positive and solar buildings are the future of tomorrow. The costs of solar panels will lower with more demand. Solar panels will also be able to capture more energy and convert it into usable electricity. One day we will see a net zero-energy country and hopefully, a net zero-energy planet.

The time will come where we have to say goodbye to conventional ways of producing electricity and I believe the solar-powered homes & buildings of today are slowly preparing us for the future.

Possible problems with the system

a) Weather-dependant

The solar system is a weather-dependant. It has an obvious requirement which is it need the sun to generate heat or electricity for solar air-condition or solar hot water system. The solar system won’t at all as there is no solar energy from the sun at night. As a result, it requires a large battery bank to store the electricity when there is sunlight so as it able to provide electricity during the night. This problem won't be a huge obstruction during summer in four seasons country. However, the problem is magnified in bad weather countries or in a bad season. It simply won’t work effectively in these areas without strong sunlight.

b) Lack of effectiveness

Installing solar system for a dwelling is not worthy as it is not a 100% efficient converting the heat energy to electric energy. It only takes a range from 20%-40% only where the remaining energy from the sun is wasted as heat energy. So it will take a long time which is

around 10-20 years to overcome its cost. This is why the solar system is not recommended for dwelling. Although photovoltaic cells have been discovered which has 43% higher efficient and able to produce more electricity, but these require high technology and expensive to manufacture.

c) Problem of semiconductor

Expensive semiconductor materials are used in the solar system to generate electricity by converting heat energy from the sun into electrical energy. However, when the temperature is increased until the semiconductor can withstand and also operating for a long time, the semiconductor may malfunction and decrease the efficiency of the solar system. If a semiconductor in a solar panel is malfunction, it will cause the energy generated by the other solar panel surrounding it to be drained. This is because the malfunction solar panel acts a resistor and decreasing the efficiency of the solar system

d) Surface of the solar panel

It required a regular time for maintaining and cleaning the surface of the solar panel which is the frame in order to maximize its efficiency. A small portion of dust, dirt or other object that have accumulated and blocked the solar panel from receiving the light energy from the sun will reduce the efficiency of the solar system. During winter, it required to remove the snow on the top of the panel that had blocked the sunlight from the panel.

e) Solar water heating system

For solar water heating system, some of the parts in this system such as control, sensor and pumps are needed to check to ensure they work effectively. If the pump has been sized to just barely overcome the pressure head of the collector loop, an unexpected added resistance can stop all flow through the collector. Besides antifreeze sensor must be maintained as If the system has a freeze sensor, but malfunction, a power failure during a freeze could result in pipe rupture. Hence, annual maintenance is needed

Recommendations for Future Improvements

Use multi-cell gallium arsenide with three-junction concentrator as cell for the solar panel. It was discovered as the highest efficiency technology with approximately 44% efficient, which has 3 times more effective than photovoltaic cell. However, it is unaffordable to manufacture with technology nowadays and it's too expensive to produce in a large amount.

The sun doesn't shine 24 hours a day, which means that the solar system able to generate electricity during the day. Develop a large energy storage system where it can store and provide electricity for us to use even though without sunlight but still able to continue providing enough and stable electricity for a long period. Recently, a research found that a new energy storage solution using a molten salt storage technology in PV systems. The inorganic salt able to transfer heat energy to the solar plant which would generate higher power output.

The government can establish subsidies for solar deployment and provide subsidies for purchasing solar panel either for dwelling or company. Establish subsidies so as able to support solar technology and accelerate the research of the material for cell which can perform the highest efficiency and affordable for all citizens. Besides providing subsidies for purchasing able to lower the cost of the solar system and citizen can less depend on electricity produced from the power station.

Learning outcome

From this project, we have learned much more about the services in buildings. We have learned much more about solar energy and the benefits of it. Especially in the case study, it has really opened our eyes on the development of solar energy and its integration to the building.

We can also see that there are many advantages of solar energy, and the disadvantages of

solar energy can hopefully be fixed and negated in the future. This can really help reduce the use of energy and can help in protecting our Mother Earth.

Furthermore, we have learned much more about ways of doing research. We found ourselves
being able to research better than we did before. This research about solar energy has really opened our eyes about how much the modern development and construction is leaning towards a green approach. It can be seen that most developers are trying to reduce our carbon footprint and use more green tactics like natural ventilation, natural lighting, solar energy & others.

Moreover, we have gained more knowledge by researching the information regarding solar energy online. We have learnt about the history and facts about solar energy and it helps us a lot in understanding. For example, we learn the size of the sun compared to earth and how much sunlight does the earth receive from such a long distance.

Lastly, we have improved our skills in doing work with my groupmates. We find ourselves taking more initiative and leading the group. We have also communicated with my groupmates more often and have really enjoyed our time. We feel really grateful to be given such a chance to do a research about something we have a passion about. We believe in a fully green future for us and our upbringing.

Conclusion

Although solar energy is very useful in many applications and comes in abundance, scientists conclude that the sun will be extinct after billions of years. Even though the size of the sun is 109 times the diameter of the earth, its energy will still come to an end in the future. Therefore, humans should appreciate this free source of energy given by the sun and use it wisely. However, solar energy may has some imperfections although it has a lot of advantages. For instance, sunlight cannot be collected at night and not every places receive the similar amount of sunlight. Humans do seek improvement to fix all this issues, for example sunlight can be collected in a storage device such as battery so that the solar energy can still be used at night.

To make solar energy better, humans do research and development so that they can fully utilize this “gift” provided by the sun. Even until today, the most efficient solar cell technology is only able to convert 20% of the sunlight into electricity, but with the increasing advancement of humans in solar cell technology, the number is likely to increase in the future. We believe that all houses in the world will be installing solar panels in their houses and reduce the amount of electricity used by the future. More people should start their investment on solar panels and they will realize its full potential after a certain period of using them. Lastly, solar energy is one of the most efficient alternative energy, so we hope that humans can depend on solar energy and stop relying on non-renewable energy such as fossil fuels before they come to an end. A journey of a thousand miles starts with one step, after all, we should not be afraid to try because if we believe, we can achieve

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