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MAE 302(001)

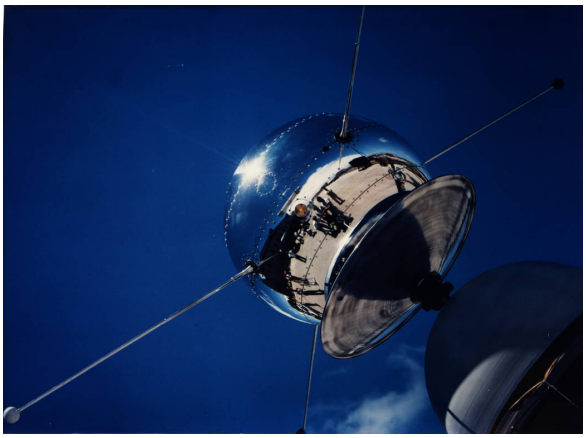
Recent Advancements in Solar Energy

Introduction

As one of the many ways to produce renewable energy, solar power is an ever growing industry. It can be used in many ways, both commercial and residential. There are an infinite amount of benefits to using solar energy over others, the main one being the constant source of power - the sun. Not only are there moral benefits, there are cost benefits as well. Solar energy is cheaper and cleaner than energy produced from fossil fuel burning power plants, and having solar panels on a residential house increases the value tremendously. Commercially it requires large amounts of land and money, but the return on investment is significant enough to cover the initial cost. Without mentioning the rapidly approaching consequences of the constant emission of fossil fuels into the atmosphere, this should still be an option considered by all. The technology behind it is constantly changing and improving, and will be forever. It is being used more and more by cities and countries around the world, and that usage will only increase as time goes on.

Background on Solar Panels

In the 1800s many physicists began to discover that energy can be obtained from the use of the sun and began to develop the groundwork for solar energy. The first working solar cell was created in 1883 and was made out of selenium. The efficiency of converting sunlight to energy was less than one percent, however, this discovery gave way to the beginning of many more solar energy discoveries. In 1954 Bell Labs created a solar panel with many different solar cells made out of silicon. The silicon solar cells were 6% efficients, much greater than any of the attempts made through the use of selenium. Silicon is the material that continues to be used today.



Spacecrafts were some of the first objects that solar energy was able to be used on. The satellites had solar panels attached that were able to harvest sunlight and produce electricity. The Vanguard Satellite 1 was the first solar-powered satellite in the world, which launched from Cape Canaveral in 1958. Solar energy used in outer space was groundbreaking for future uses of solar energy in homes and commercial buildings. In the 70s, the shortage of oil created a need for the United States to find other energy sources

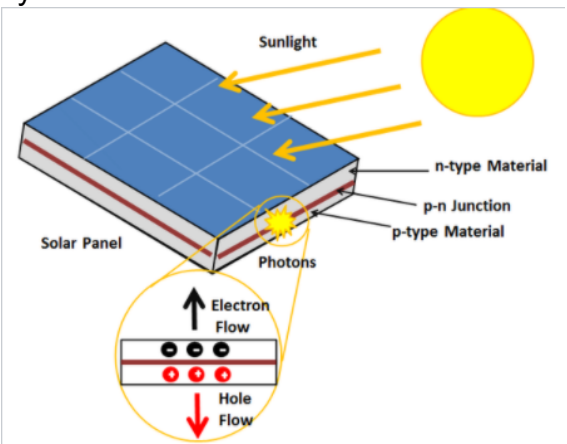
elsewhere. Solar panels were installed onto the white house which brought awareness to the possibility of using them in other places as well.

This increase in the use of solar panels increased the amount of research conducted which ultimately led to a increase in the efficiency of solar panels and a decrease in the price. Current solar panels on a home are around 15-18% efficient and cost around $0.50 per watt. This is a huge improvement from the original solar cells that were less than one percent efficient and cost close to $300 per watt. In 2016 the United States had installed 1 million solar installations after the industry had been around for 40 years, but it only took 3 years after that for the United States to have 2 million solar installations. Solar energy has had a huge impact on where the energy that we use comes from. It is becoming more prominent in our society and will continue to give us a renewable source of energy that is beneficial today.

Different types of solar energy

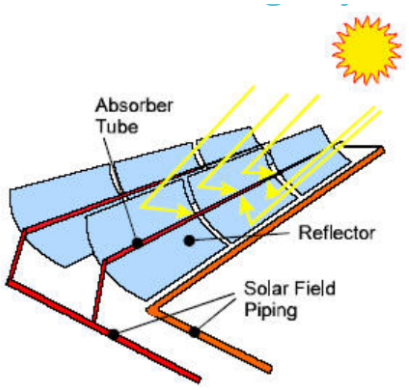
There are two main types of solar technology used today, which are Photovoltaics and Concentrated Solar Power. Photovoltaics use photovoltaic cells(PVs) inside a solar panel to capture sunlight and turn it into electrical power. This is done in solar farms, which usually consist of many solar panels. SAS has a solar farm in Cary, NC which has over 10,000 solar panels in it. It can produce more than 3.6 million kWh annually, which is enough to power more than 325 average US households. On a smaller level, solar panels can be put on houses to provide personal electricity. While it is a high initial investment, the return usually outweighs it. There are many factors that go into determining whether or not they will be cost beneficial, mainly the quality of sunlight on the roof of the house. Concentrated Solar Power (CSP) uses heat from the sun to generate thermal energy. This can power heaters and turbines which create electricity. Instead of using PV cells, curved mirrors - heliostats - are used to reflect sunlight and use the heat produced. In the Mojave Desert of California, the Ivanpah Solar Electric Generating System uses over 150,000 heliostats to generate over 350 mW of electricity. This is enough to power over 100,000 American homes. Unlike PV, CSP cannot be used on a personal home, it can only be used on a solar field.

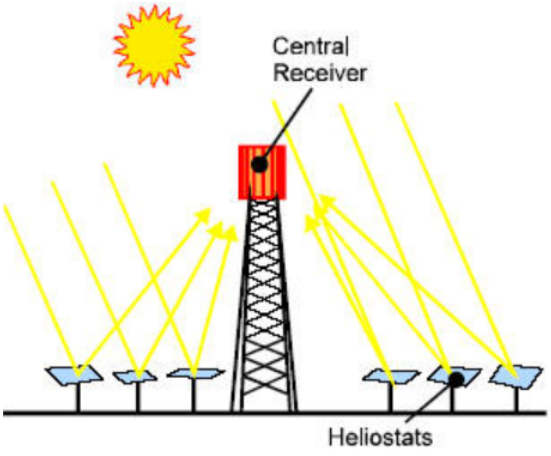
PV cells (shown to the right) are used to harvest and convert solar energy into electricity using the photovoltaic effect. They are made up of multiple layers, all of which are used in the energy conversion. The layer that does the actual conversion of energy is the semiconductor layer, which is made up of two smaller layers within. The two inside layers are different types of semiconductors - a p-type and n-type. They join



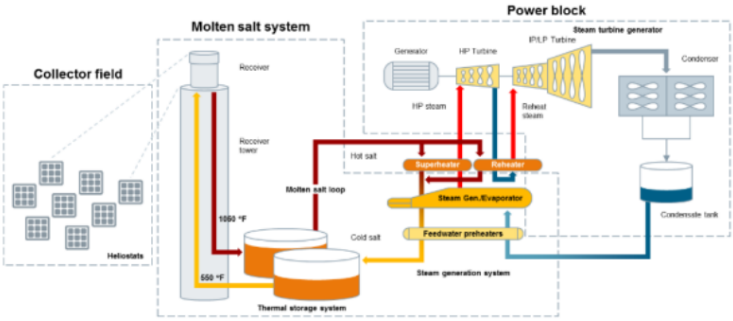
together and form a p-n junction, which creates an electric field where the electrons move to the positive p-side and the electron holes move to the negative n-side. This creates a field where negative charges move in one direction, and positive charges move in the other. When light hits the cell, the photons transmit energy to the electrons on the p-side causing them to jump to a higher energy state. This is known as the conduction band, and in this state the electrons can move through the material and create the electrical current in the cell. On either side of the semiconductor layer are layers of conducting material. This is used to collect the electricity produced by the semiconductor. The backside of the cell (facing the ground) is completely covered in conductive material, however the top of the cell is only partially covered in order to let the sunlight hit the semiconductive layer. There is also a final addition of an anti-reflective coating on the top of the cell, which prevents the loss of sunlight to reflection. The semiconductive layer is naturally very reflective, and this layer helps to absorb more of the solar radiation. After collecting this electricity, a transformer is used to convert the DC current in the PV cell to AC current to feed into the electrical grid. This goes directly into buildings and homes, or it can be stored using a lithium ion battery.

CSP also creates electricity, but in a different way. The most used and best proven way to use CSP is with the Parabolic trough technology(shown to the right). Using the heliostats, the sunlight is reflected off hundreds of mirrors all directed onto an absorber tube(receiver). This tube contains a high-temperature heat transfer fluid (usually synthetic oil) which is heated using the reflecting sunlight. The fluid then passes through a heat exchanger where it is used to heat water, which then turns into steam. This steam powers a conventional steam turbine power system to generate electricity. The heliostats themselves are programmed to track the sunlight throughout the day, which allows for maximum absorption of sunlight throughout the day. CSP can also be used with a power tower, where the heliostats are all directed towards a singular tower - the central receiver(shown to the right). The heat transfer fluid or molten salt is housed in the tower, and heated to approximately 600°C. This fluid is again used to heat water into steam, which is then used in a turbine-generator to produce electricity. In comparing the two methods, the use of the power tower seems to produce more steam. This would be caused by the





sunlight all directing to one main spot, which allows the heat transfer fluid to become hotter and stay hotter. This would produce more steam when the fluid flows through the heat exchanger. The molten salt is a relatively new concept, and can store more heat than the heat transfer fluid. It is used in the power tower system, and is another reason why this system produces more steam. It can reach a higher temperature, and stays hotter for a longer time than the oil. It also provides a method for energy storage because it takes so long to cool off. Once it is heated in the receiver, it can be either used immediately to heat the water, or stored thermally in a hot tank where it can be used later. The process using molten salts is shown to the right, all the different steps can be seen in the diagram. While the parabolic trough system is more practiced and tested, the power tower system is upcoming and slowly being used more throughout the world.



Solar energy in homes

In our society today, solar energy has become an increasingly prominent and obtainable source of energy. It can be used for electricity, water heating, ventilation and lighting within residences. When solar energy was first becoming an option it was incredibly expensive to install and to continue paying for, especially in comparison with the more frequently used sources of energy. However, nowadays using solar energy can actually save money. The amount of electricity used, size of the residence and size/angle of the roof, hours of direct sunlight on the solar panels, and local electricity rates all have an effect on the efficiency and cost of solar energy, but in many cases this can increase savings in residences. Many people are interested in purchasing homes that have solar systems attached which increases the value of homes to create more savings for the homeowners as well. The cost savings that come with using solar energy in homes are very beneficial, but pale in comparison with the environmental benefits that solar energy brings. The use of solar energy in homes reduces the greenhouse gas emissions such as CO_2 and other dangerous pollutants such as sulfur oxide and nitrous oxide. The solar panels also require minimal maintenance after they have already been installed.

The initial cost of solar panels can be expensive. Between the cost of the solar panels themselves and the installation, it can cost around $20,000 to have them installed. For people who do not plan on living in the same home for a long period of time, this can be an unreasonable investment because they will not be able to get much of the financial benefits in a short period of time. Solar panels are installed onto the home and incorporated throughout the electricity in the home so it would not be possible for them to be moved. Another drawback to residential solar panels is that they require sunlight to work. In areas that are generally fairly cloudy or it rains a lot, solar energy might not be the best solution because sunlight is needed to get energy from the solar panels and in locations that go many days without sunlight, the use of solar energy is not feasible. Since solar energy is a newer source of energy, not all locations throughout the country have access to companies that will provide solar energy to them. In rural areas or areas outside of a specific zone, it could be challenging to get a company to come outside of their coverage area to install solar panels and provide energy to these homes. On the other hand, in the middle of a large city homes are much smaller and many people live in apartment complexes or residential areas that do not have enough space to install solar panels. Solar panels take up a lot of space, about 100 square feet of roof for 1 kW, which requires more space than some inner city homes provide. There are many advantages to using solar energy within residential homes and recent advancements in solar energy have continued to improve the conditions and efficiencies of solar energy. However, there continue to be challenges that will need to be overcome.

Commercial Solar Energy

With the two different types of solar energy come two different types of solar fields. PV solar panels are arranged on a solar farm, also called a photovoltaic power station(shown to the right). They are directly connected to the power grid, and usually owned by utilities in order to power their coverage area. Utility-scale solar farms will be at least 1 MW which can supply 200 households with power. The cost of large scale solar installations is around $1/Watt, which means a small-scale utility solar farm would cost around $1 million to install. However, this is just a small solar farm. The largest solar farm in the world is the Pavagada Solar Park in India. It is a 2,050 MW array, which would cost over $2 billion to install. However, this can supply energy to hundreds of thousands of households, so the return on investment would be extremely beneficial to the consumer.

The downside of the huge solar farms is the amount of land it takes to create. The Solar Park in India takes about 2,500 acres of land, but smaller solar farms can be placed on only a few acres of land. The benefits of solar farming are immense, not only because of the cleaner energy, but also the cost benefits. Solar farming produces little to no pollution, and the construction pollutants are heavily outweighed by the effects of the clean energy produced. They are also a good return on investment, where the cost of electricity is lower from a solar farm. This means the electricity companies who buy power off the grid don't have to pay as much for power from the solar farms, and therefore wouldn't charge users as much.

Heliostats are used at CSP plants, which are much more extensive than the solar farms used by the PVs. Unlike the PVs they cannot just be hooked up to the power grid, they must be attached to a power plant to create electricity. An example of a power tower CSP plant is shown to the right, where the receiving tower can be seen in the middle with all the heliostats directed towards it. They are more expensive to set up than the PVs, and can create more pollution from the plants. They depend more on the heat of the sun than the light, so the areas they can be effective are limited. In the US, the best locations for the CSP plants are in the Southwest. They require a lot of land, usually about 5-10 acres per MW of capacity. Most effective plants are built in sizes of 100 MW and higher, meaning they require at least 500 acres of land. The more land used, the more space the plant has for energy storage. CSP plants also require access to water, as they use it for cooling purposes inside the plant. They also need access to the transmission grid to deliver electricity to the users. Even with all the restraints on the location of the plants, they are still used throughout the southwestern US. They provide power to hundreds of thousands of residents there, and save the cities ample amounts of money.

Future of solar energy

Currently, solar energy only accounts for 1% of the global energy consumption and is an even smaller percentage for the United States alone. However, over the next few decades solar energy will inevitably become more prominent because the need for more renewable energy is continually increasing. The global climate change is one of the biggest reasons that solar energy will be needed more in the future. The current CO_2 emissions that come from fossil fuels have the largest negative impact on climate

change and ⅔ of these emissions are associated with heating, electricity and transportation. Using solar energy will be a positive solution to this growing problem and could tremendously decrease the amount of CO_2 emissions released into the atmosphere.

Research is currently being conducted to determine if there is a more efficient material to use within the cells other than silicon. Silicon has been used for many years and is continuously being improved, but another type of material could have a positive effect on the efficiency of the solar cells. The modules and inverters within the solar cell system only account for about ⅓ of the residential and ½ of large systems in the United States. Over the next few decades work will need to be done to decrease the remaining costs as they have stayed around the same price for the past few years. A potential third-party model would be a beneficial solution to decrease the cost of installation for homeowners. In this model the homeowner buys energy from the third party that owns the PV system. This would give homeowners the opportunity to use solar energy with less of a cost up front but would still be decreasing the amount of fossil fuels that are used as the primary energy source. This model is beneficial because the average cost of solar energy for residential homes is larger than for utility-scale systems, but would still give residences the opportunity to use solar energy

Within utility-scale systems the cost from a CSP plant is higher than the cost from a PV plant and both plants are higher than the cost for fossil fuels. The best way to decrease the prices of both of these would be to reward the use of solar generation. There are some subsidies available for solar technologies rewarding investment. This is a decent solution currently in place, but subsidies for solar generation would be much more beneficial. Federal investment tax credit should also be replaced by grants which are much more effective. The government will have to continue to support the renewable energy cause in order for the nation to be able to cut down on the amount of fossil fuels, which will be crucial over the next few years and decades. During this time solar energy will inevitably become more prominent and in turn more effective.

Conclusion

Solar energy has been around for a few decades, and recently has become a much more prominent and effective source of energy. Solar energy is obtained from either Photovoltaics or Concentrated Solar Power to provide energy to both residential homes or used at a utility scale. The processes to collect solar energy and the equipment that is used have been modified multiple times and are incredibly efficient and effective. These technological advancements are making it possible for solar energy to be used more frequently in our society instead of the sources that can be detrimental to our environment.

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