**Solar Photovoltaics :**
**Fundamental Technology and Applications**
**Prof. Soumitra Satapathi**
**Department of Physics**
**Indian Institute of Technology-Roorkee**

**Lecture - 02**
**Introduction to Solar Energy**

Hello everyone, welcome to the second module of our course. In the last class we have discussed about different source of conventional energy. In that class we have discussed that there are major three sources of conventional energy. One is oil, another is coal, another is the natural gas. And we also said that these three sources are called fossil fuels.

Because they have been actually inherited by burning and all the plants and the animals they have been buried under the swamps over the times and during the time by the pressure and temperature slowly they have been converted into these fossil fuels. We also discussed that these fossil fuels have some environmental impacts. Like they add to the global warming.

Also they are also very hazardous to the human health. Because of that, like we have to find out some alternative energy sources. In today's module, we will talk about what are the different source of non-conventional energies. Sometimes they are also called the renewable energies.

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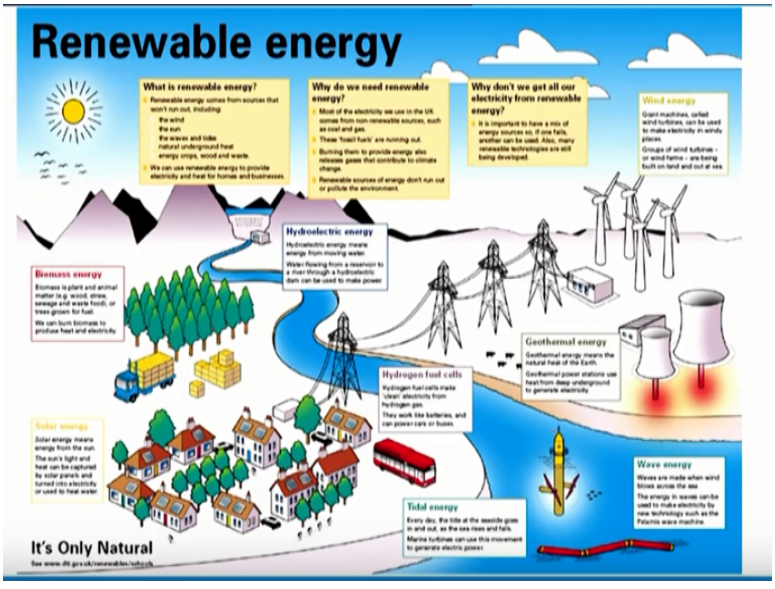

So in this diagram we are showing that what are the different source of renewable energy. As you can see from the picture, we have solar energy, we have wind energy, then we have tidal energy. And also we have hydro electric energy, hydrogen fuel cell and biomass energy. And of course our favorite solar energy, which we will discuss in details. In this module we will talk about this different source of energy briefly. And finally, we will start about the solar energy, okay.

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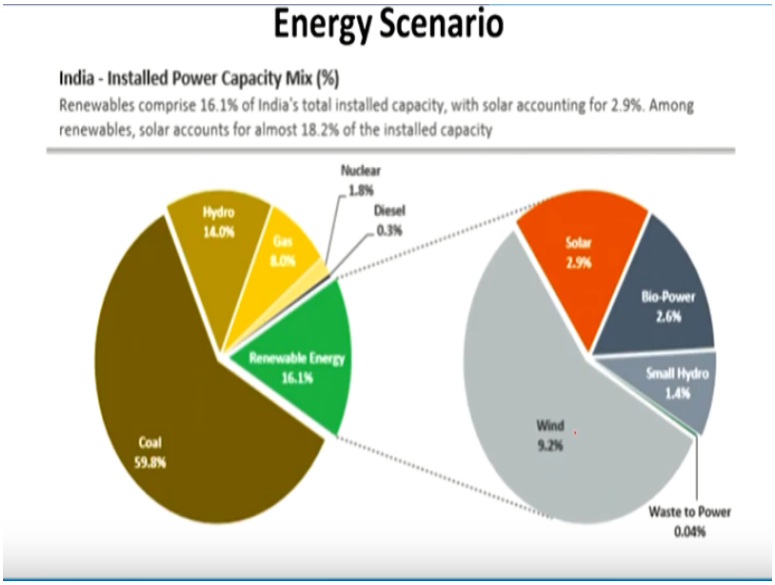


If we look at the Indian scenario, this pie chart is showing the distribution of the energy sources from different resource. As you can see from this pie chart, the coal is still the major source of energy, it is 59.8%. Whereas, the renewable energy consist only 16.1%. Out of that the solar cell consists only 2.9%. So this means there is a huge room of improvement in this sector. Among renewables solar accounts or for almost 18.2% of the installed capacity.

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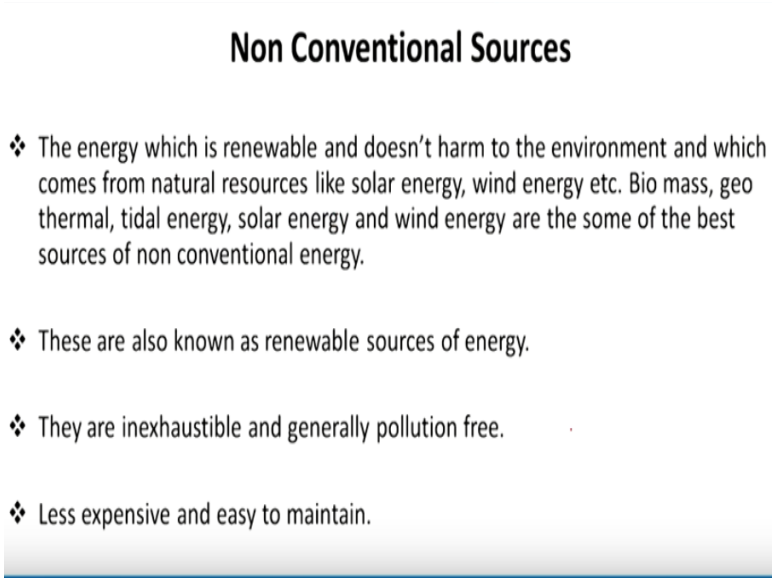


So what is the definition of non-conventional source? The energy which is renewable and does not harm to the environment and which comes from the natural resources, like solar energy, wind energy, etc. Like for example, solar energy. In our lifetime and few of our future generation lifetime science will be there. So that means these resources is unlimited.

And solar energy also leaves very least amount of carbon residues as a byproduct. Therefore, it is a very clean and green source of energies. Some favorite other example of this non=conventional energies are biomass, geothermal, tidal energy and wind energy. This sources of non-conventional energy sometimes they are also called renewable energy as you can renew it over and over from the natural resources.

They are in adjustable and generally pollution free. It is worthwhile to mention that, although like for example when you make a solar cell, you generate some secondary pollution. But usually that does not leave any carbonious product like carbon dioxide, or carbon monoxide, which is usually the case for burning the fossil fuels. That is why the environmental impact or the hazardous impact of this kind of energy resources are very small.

And also they are less expensive and easy to maintain. Let us discuss about the different source of the non-conventional energy one by one. First we start with the wind energy.

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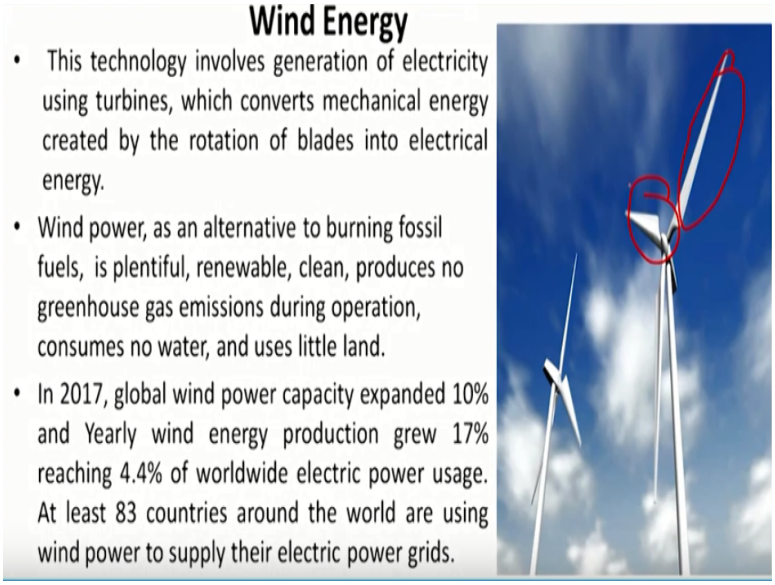


This technology impacts the generation of the electricity using turbines, which converts the mechanical energy created by the rotation of blades into electrical energy. In this figure, for example this is a wind power mill, the picture has been taken and you see the blades here. And when the wind flows, this blade rotates. And the rotation which is basically the mechanical energy that converts to the electrical energy.

Wind power as an alternative to burning fossil fuels is plentiful, renewable, clean, produce no greenhouse gas emission. And also during operation they do not consume any water and use also very little land. In 2017, global wind power capacity expanded 10% and yearly wind energy production grew 17% reaching 4.4% of worldwide electricity power usage.

At least 83 countries around the world are using wind power to supply their electric power grids. What is the mechanism of the wind energy? Or how does the wind energy is produced, we just explained.

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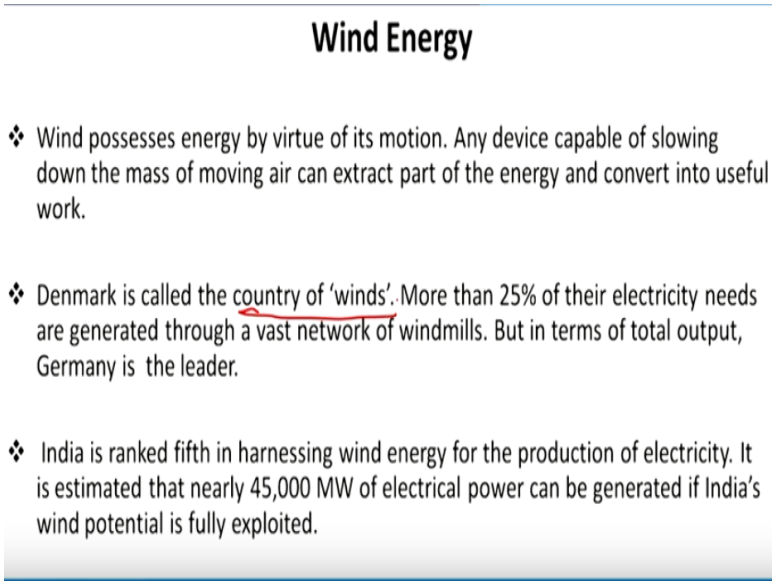


But one more time, wind possess energy by virtue of its motion. Any device capable of slowing down the mass of moving air can extract part of the energy and convert into the useful work. So basically wind is flowing and then this blades, so they try to slow down the wind and in this process, whatever the mechanical energy has been generated, that is converted to the useful form of the energy.

So Denmark is called the country of winds. There are lot of useful winds in the Denmark. More than 25% of their electricity needs are generated through a vast network of windmills. But in terms of total output Germany is still the leader. India is ranked fifth in harnessing wind energy for the productions of the electricity. It is estimated that nearly 45,000 MW of electric power can be generated if India's wind potential fully explored.

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Let us take an example, where in India the wind mill or the wind turbine has been installed. A very famous example is Dhule in Maharashtra where you can see that the rural people are getting benefited by this wind energy.

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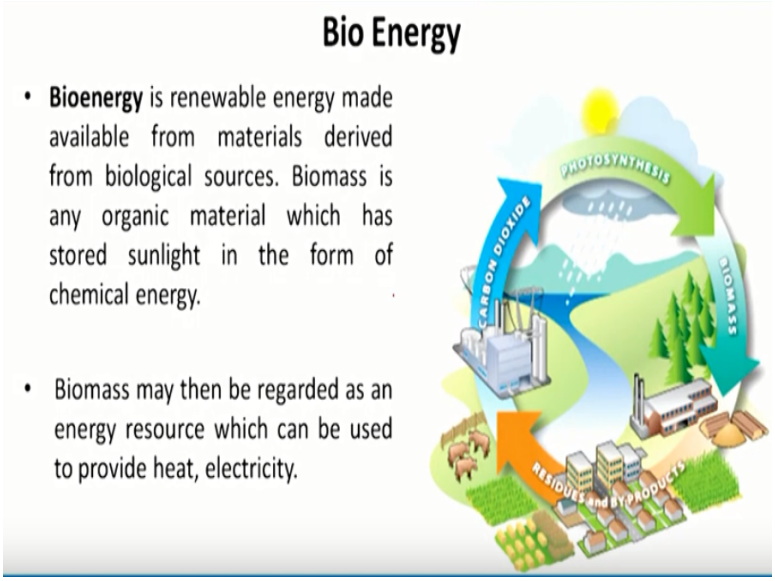


Okay, the second popular form of this non-conventional energy is the bioenergy. Now what is a bioenergy? Bioenergy is renewable energy again made available from materials derived from biological sources. Biomass is an organic material which has stored sunlight into the form of chemical energy and when the aerobic or anaerobic degradation happens then the stored chemical energy slowly converts to the useful form of the energy which we can use it later on.

Biomass may be regarded as an energy resource which can be used to provide heat as well as electricity. But can we call all these natural resources or can call everything as a biomass?

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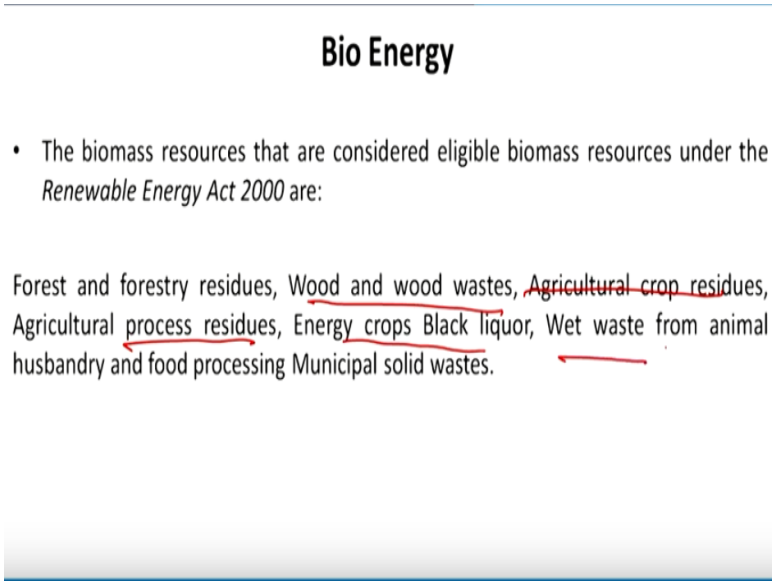


According to the Renewable Energy Act 2000, forest and forestry residues, wood and wood waste, agricultural crop residues, agricultural process residues, energy crop black liquor and wet waste from animal husbandry and food processing municipal solid waste, they are categorized as the sources of bioenergy. The third important form of energy is the tidal energy.

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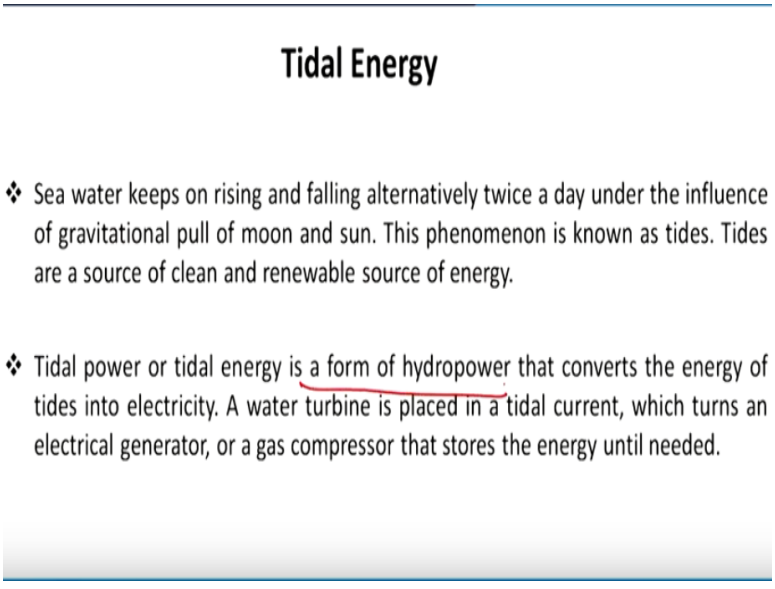


Seawater keeps on rising and falling alternatively twice a day, under the influence of gravitational pull of moon and sun. This phenomena is also known as tides. Tides are

a source of clean and renewable source of energy. Here we are using hydropower instead of in the case of windmill we use the wind power, here we are using hydropower to generate the electricity or to move the turbine.

So tidal power or tidal energy is actually form of a hydropower that converts the energy of the tides into the electricity. A water turbine is placed in a tidal current, which turns an electric generator or a gas compressor that stores the energy which is finally needed.

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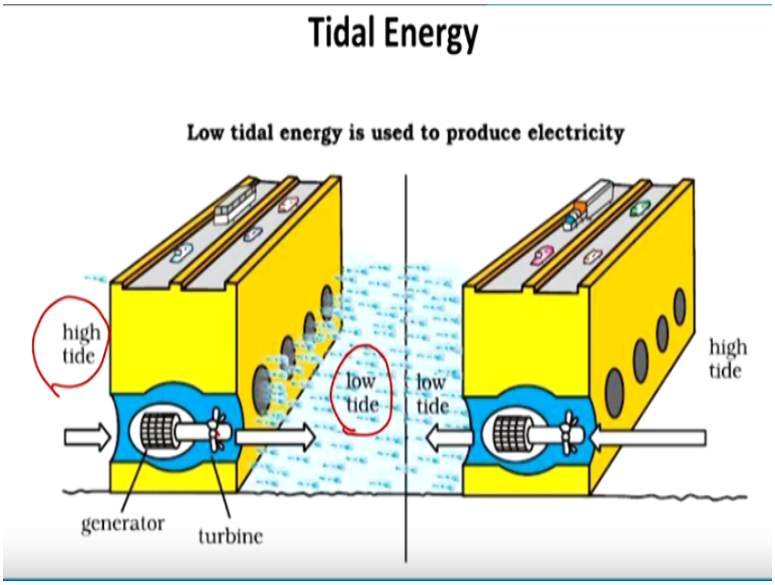


A graphical representations will be more helpful to understand this concept. Let us consider there is a high tide area on the left hand side and there is a low tide area on the right hand side. This is the device which we have made to use this tidal energy. Now when this the workflow go and hits this device, the generator and the turbine, this turbine moves. And that movement that mechanical energy rotates the generator and that converts the mechanical energy into the electric energies.

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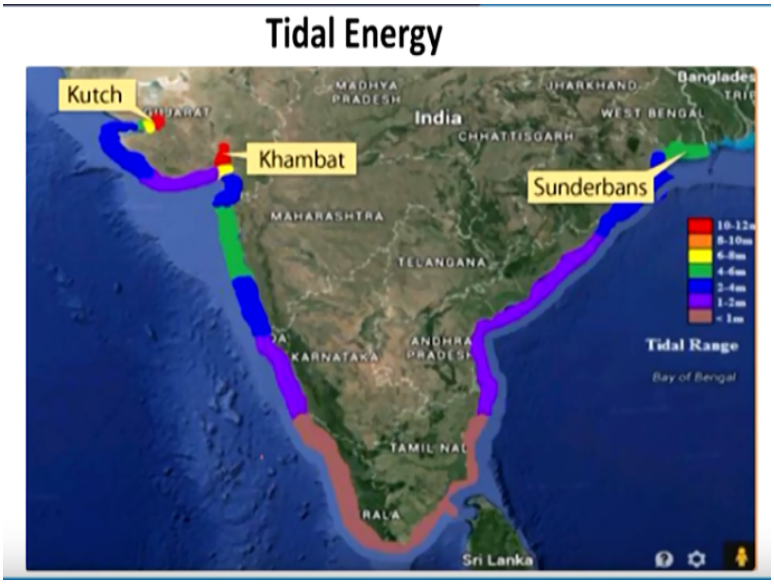


In India there are coastal areas like Sunderbans in West Bengal and in Khambat and in Kutch, we have this tidal energy power plant.

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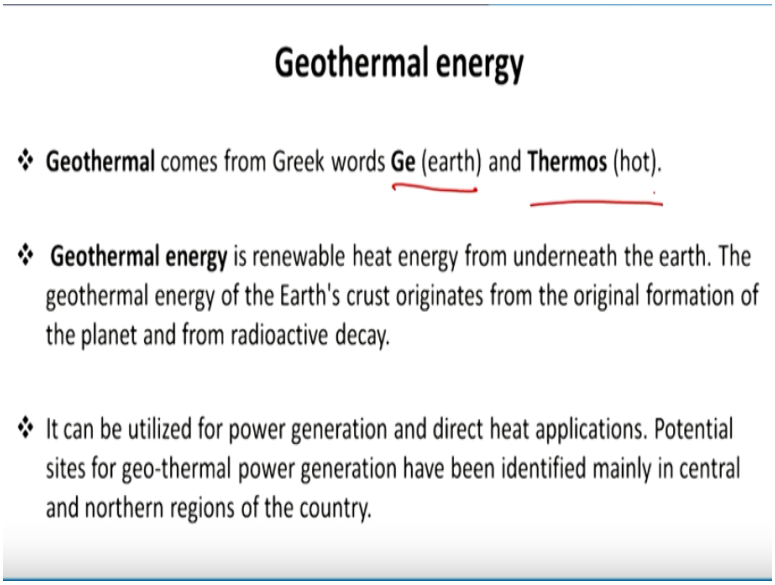


The fourth important form of energy is the geothermal energy. Geothermal comes from the Greek word, it has Ge which means earth and Thermos means hot. So geothermal means something hot from the earth. Now the earth mantle or the earth crust have some good amount of heat. The idea was if we can able to extract that amount of heat and heat the water to rotate the turbine, then we can make useful energy out of that. And that was the concept behind geothermal energy.

So it is again a renewable heat energy from underneath the earth. The geothermal energy of the earth crust originate from the original formation of the planet and from

radioactive decay. It can be utilized for power generation and direct heat applications. Potential sites for geothermal power generation have been identified mainly in central and northern regions of the country.

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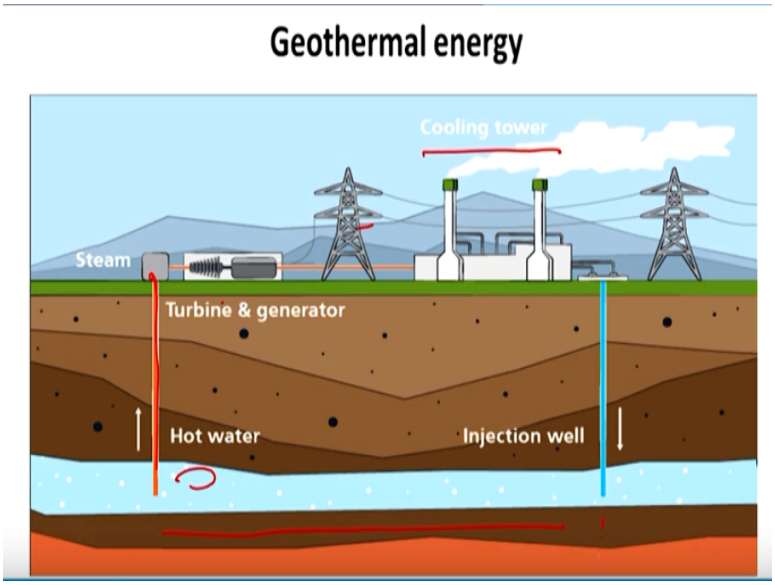


In this diagram, we are explaining the mechanism of geothermal energy generation. As you can see, this is the earth crust or the mantle, which has a good amount of heat. Now this heat is used to make this water hot. Now this hot water goes up, makes steam and then this steam rotates the turbine. And from there we get the useful amount of the electrical energy here and the rest of this unused hot water go through this cooling tower.

And after getting cooled so they comes back to this well through the injection well and this whole process rotates or this whole process circulates. That is why the geothermal energy has been generated.

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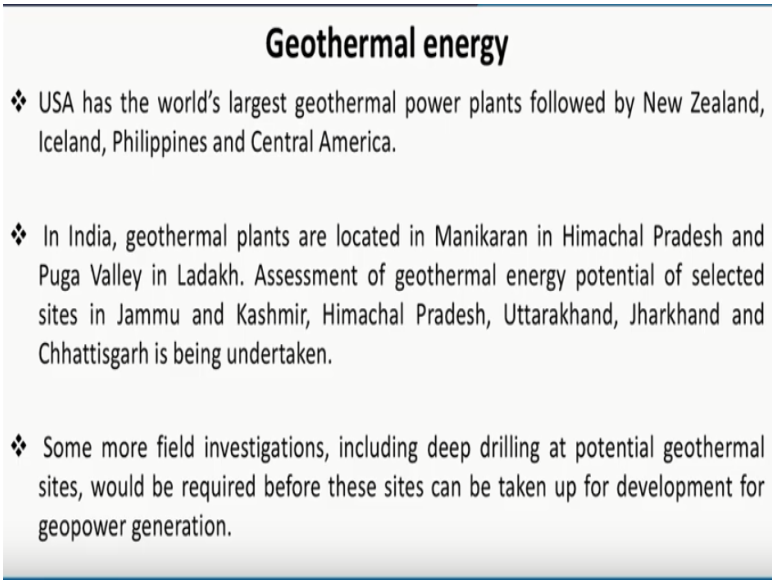


USA has the world's largest power plant followed by the New Zealand, Iceland Philippines, and Central America in the case of geothermal energy. In India, geothermal plants are located in Manikaran in Himachal Pradesh and Puga Valley in Ladakh. Assessment of geothermal energy potential of selected sites in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Jharkhand and Chhattisgarh is being undertaken.

So there is a new possibility that we can always explore new sites, which is rich in this geothermal energy and we can use them. Some more field investigations including deep drilling at potential geothermal sites would be required before these sites can be taken up for development for geopower generation.

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In this picture, we are showing geothermal energy productions in the Himachal Pradesh at Manikaran. You can see that a huge flow of the water which is getting heated and you find the steam here and the steam is actually used to rotate the turbine which is used to finally to get the electricity.

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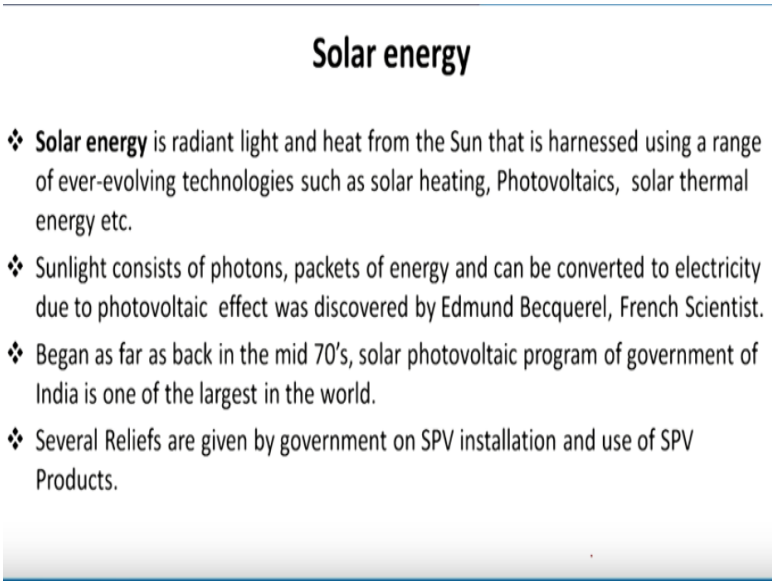


Finally, we come to our solar energy. Solar energy is radiant light and heat from the sun that is harnessed using a range of ever evolving technologies such as solar heating, photovoltaics, solar thermal energy, etc. It is worthwhile to mention that this solar energy comes through different stage. It is said that Rome is not built in a single day. Similarly, discovery of the new materials has led to the new technologies in the solar cells built.

Based on that, we classify the solar cell either as first generation, second generation, third generation or fourth generation solar cells. In later on in our course, we learn in details about this various generations of the solar cell. Sunlight consist of photons packet of energy, and can be converted into the electricity due to the photovoltaic effect, which was discovered by Becquerel, a French scientist.

Began as far as the mid 70's solar photovoltaic program of government of India is one of the largest in the world. Several reliefs are given by the government on SPV, installation and use of solar photovoltaics products. SPV this acronym stands for solar photovoltaics.

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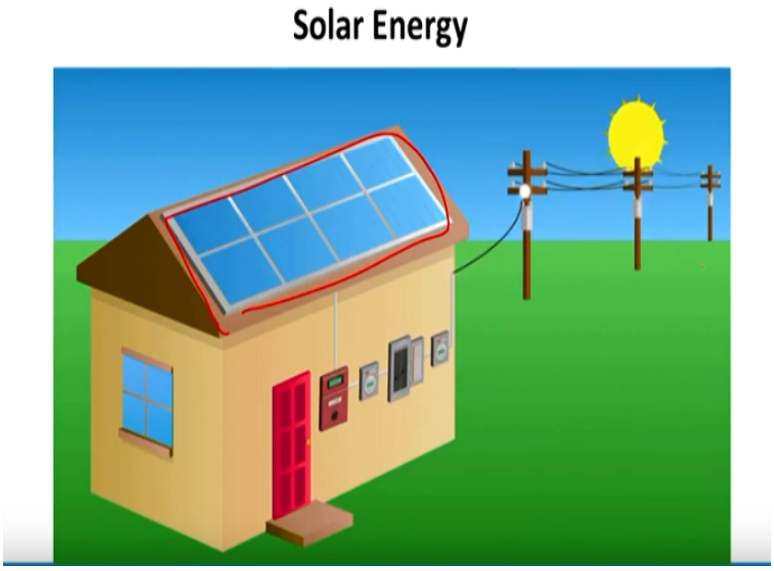


This is a typical diagram of a solar panel which is installed on the roof of this house. You can see here. This is basically many numbers of solar cell which have been integrated and put it in the form of a module. What the solar panels does in the daytime they harness the solar energy and we store that energy.

Whatever the energy has been utilized in this building, that is recorded by the power meter and unused energies goes back to the grid and it is often taken back when it is further required. In the initially I mentioned that solar energy is one of the most important and popular source of energy among the different kind of non-conventional energy like wind energy, tidal energy or like you know hydroelectric energy. Why we made that comment?

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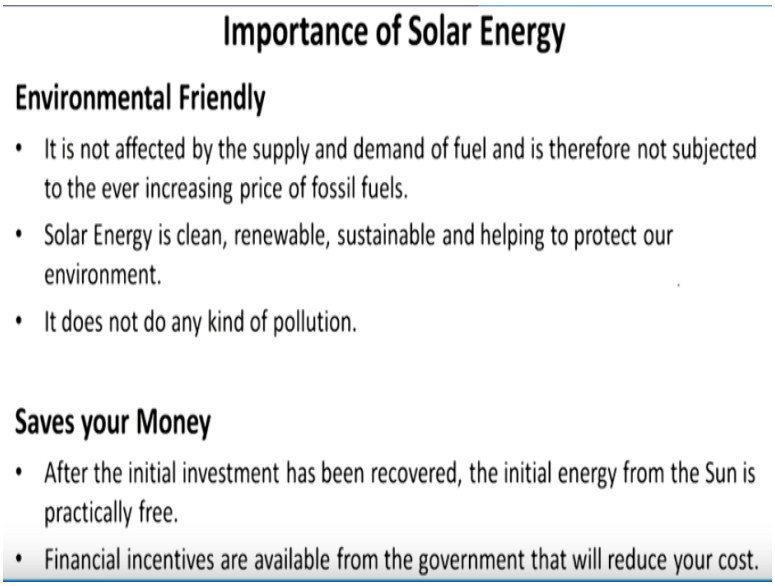

First of all solar energy is the environment friendly. It is not affected by the supply and demand of fuel. And therefore not subjected to the ever increasing price of fossil fuels. In our lifetime and future of some generation's lifetime sun will be there. So we do not have to think lot about the source of energy in this case. Second point solar energy is clean, renewable, sustainable and helping to protect our environment.

And the most importantly, it does not leave any kind of pollution. Of course, when we make solar cells, during the fabrication process, we generate a very minimal amount of secondary pollutions, but that is negligible in comparison to the amount of carbon dioxide or carbon monoxide or other greenhouse gas which is emitted during the burning of the fossil fuel.

And other important point is that solar energy saves your money. After the initial investment has been recovered, the initial energy from the sun is practically free, it goes over and over, over the time with almost no maintenance. Financial incentives are also available from the government that will reduce your cost.

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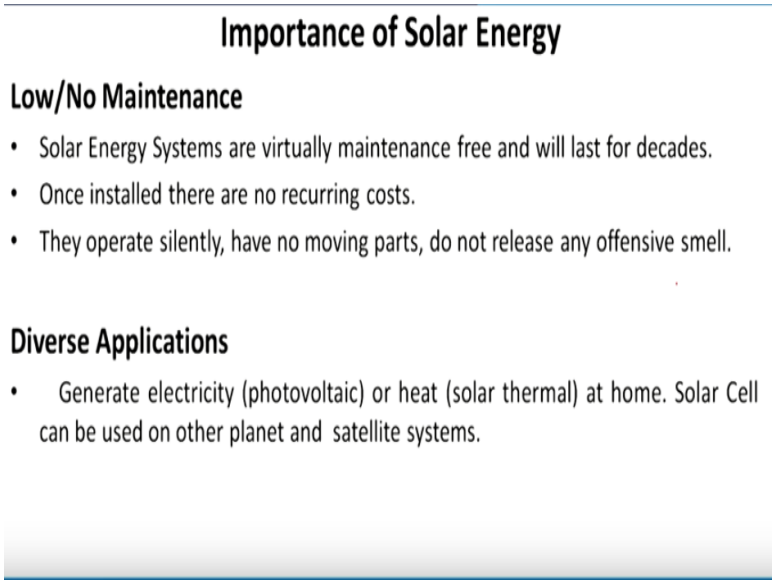


The maintenance cost of the solar energy is very low or one can say almost negligible. Solar energy systems are virtually maintenance free and will last for decades. Once installed, there is no recurring cost. Basically, unless until the panels has to be replaced we do not have to change any other components, whether in case of thermal turbines or in nuclear powers we have to deal with the every parts or we have to change it every now and then.

So that kind of problem is not existed in the case of the solar panels. They operate silently having no moving parts, do not release any offensive smell. So they have diverse applications, generate electricity photovoltaic or heat solar thermal at home. So solar energy can also be used to cook food. So there are example like solar cooker where the solar energy is used to cook the food.

So that is the classic example of the solar thermal photovoltaics. Solar cell can be used on other planet and satellite systems. ISRO and different in our country and different space organizations in other countries use high efficiency solar panel in the satellite. And that is one of the success like you know the satellite technology or the space technology is becoming more and more successful nowadays.

And we have our indigenous technologies for making our own solar panels.

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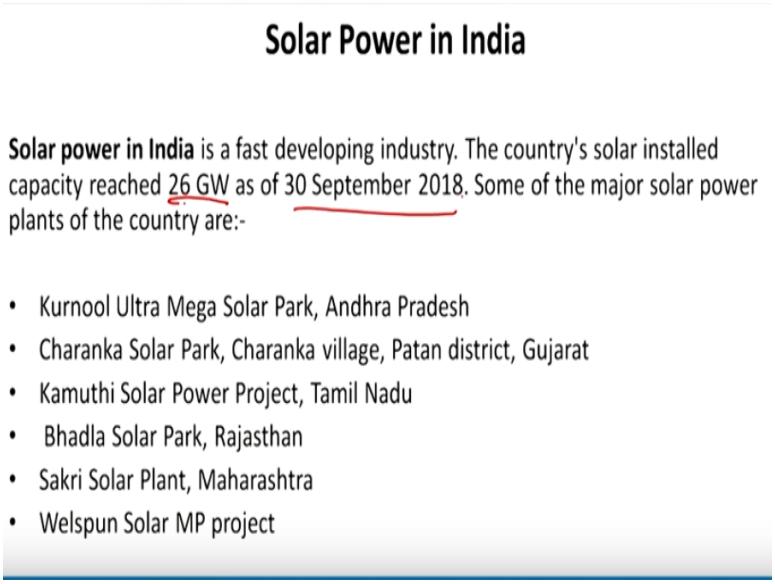


In India, solar panel is gradually the number of solar panels is increasing gradually, day by day. The country's solar installed capacity reached 26 GW. This data is as of 30th September 2018. And government has emphasized to increase the number of installation of the solar panel more and more as the days pass. Some of the major solar plants of the country are Kurnool Ultra Mega Solar Park, which is at Andhra Pradesh. Charanka Solar Park, which is at Charanka village, Patan district at Gujarat.

Kamuthi Solar Park Project, it is in Tamil Nadu. Bhadla Solar Park at Rajasthan which also recently reported a very low tariff of the solar power. Sakri Solar Plant at Maharashtra and Welspun Solar MP Project. These are some of the mega projects of the solar power plants. And apart from that we have also some small solar power plants.

And even in some academic institutions and in some households we have solar panels. Just like few solar cells make a solar photovoltaic module, similarly few solar panels come together and they make solar photovoltaic array.

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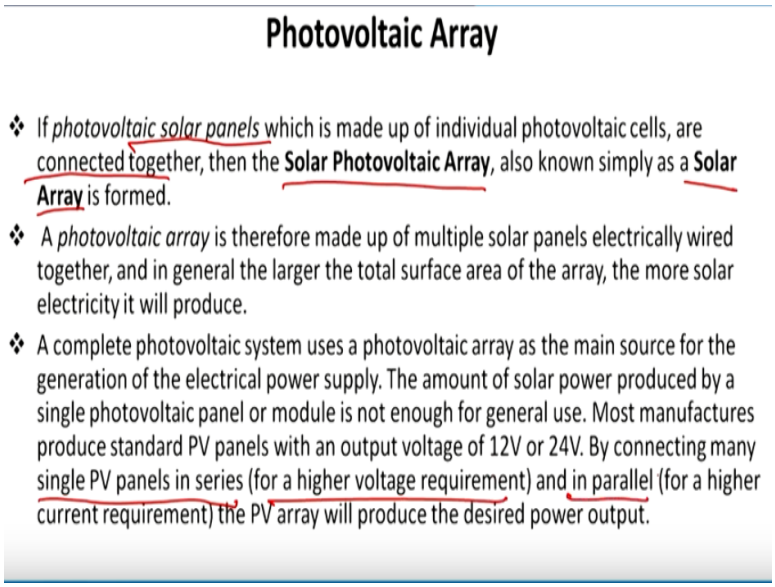


So if photovoltaic solar panels, which is made of individual photovoltaic cells, they are connected together, then what we get is called solar photovoltaic array or simply solar array. So when for example like let us say one has hundred solar cells. Once this hundred solar cells are connected we get a solar panels. But when these hundred solar panel is connected, then we get a solar array and that is useful for high amount of energy generation.

A photovoltaic array is therefore made up of multiple solar panels, electrically wired together and in generally the larger the total surface area of the array, the more solar electricity it will produce. A complete photovoltaic system use a photovoltaic array as the main source for the generation of the electric power supply. The amount of solar power that is produced by a single photovoltaic panel or module is not enough for general use.

For most of the industrial purpose or for most of the practical purpose, the amount of energy we can generate by using one solar panel is most of the time is not enough. So that is why it is **very,** very important to bring few solar panels together, where we can generate more and more energy. And that is why the concept of the solar array. Most manufacturers they produce standard PV panels with an output voltage of 12 volt or 24 volt.

By connecting many single PV panels in series for a higher voltage requirement and in parallel for a higher current requirement, the PV array will produce the desired power output. So PV, single PV panels can be connected in series for a higher voltage requirement or it can be also be connected in parallel where you need a higher current requirement. But ultimately, current times voltage is the power. So we will get the desired power output by this process.

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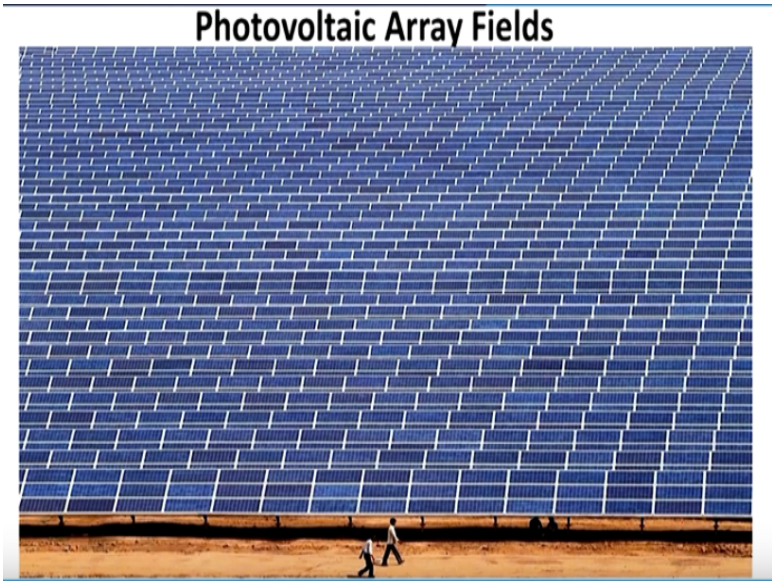


Let us take a look how does this photovoltaic array fields looks like. In this example, we are showing a typical diagram of a solar array which is installed in an industrial area in Germany. So this solar array is reported to power up a big industrial sector or big manufacturing units. So that itself shows the capacity of this kind of photovoltaic array. So far we have mentioned different sources of non-conventional energy.

We have mentioned about wind energy, we have mentioned about tidal energy, we have mentioned about geothermal energy and we also talked about the solar energy.

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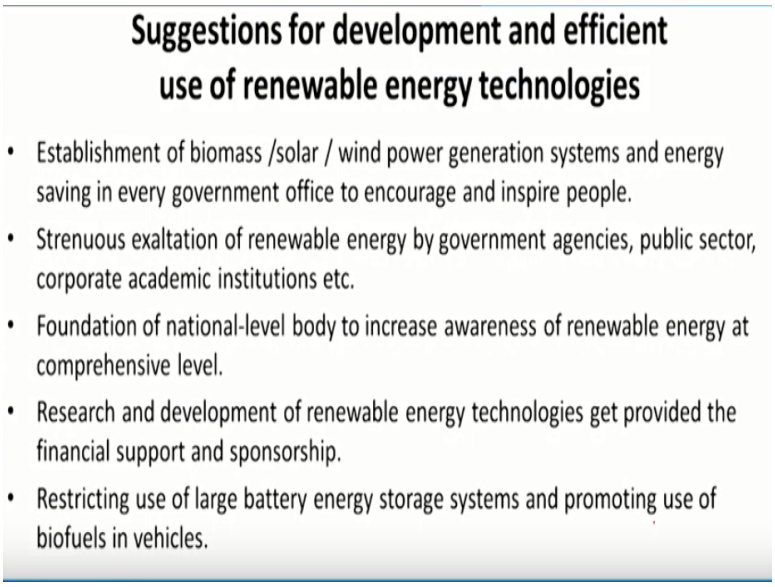


And also we mentioned about the biomass energy. Now all of this different source of non-conventional energy they are limited by the efficiency. Obviously the power generation capacity of the renewable energy resources are sometimes or many times not as high as the conventional sources of energy like burning fossil fuels. So what are the other way to improve the efficiency of these renewable solar cells or renewable energy technologies?

Let us take a look on that. What are the suggestions for the development and efficient use of renewable energy technologies. Establishment of biomass, solar wind power generation system, and energy saving in every government office to encourage and inspire people can be one alternative. Strenuous exaltation of renewable energy by government agencies, public sector, corporate academic institutions and energy can be a big initiative.

Foundation of national level body to increase the awareness of renewable energy at comprehensive level is very important. Research and development of renewable energy technologies get provided the financial support and sponsorship or government and several other agencies has understood the need of this renewable energy. That is why they have pumped lot of research funding nowadays for doing the research in renewable energies.

Restricting use of large battery energy storage system and promoting use of biofuels in vehicles. These are some of the suggestion for the development and efficient use of renewable energy technologies. So far, we have discussed about the different sorts of non-conventional energy or renewable energy. And we also gave some suggestions about the efficiency or the intelligent use of this energy.

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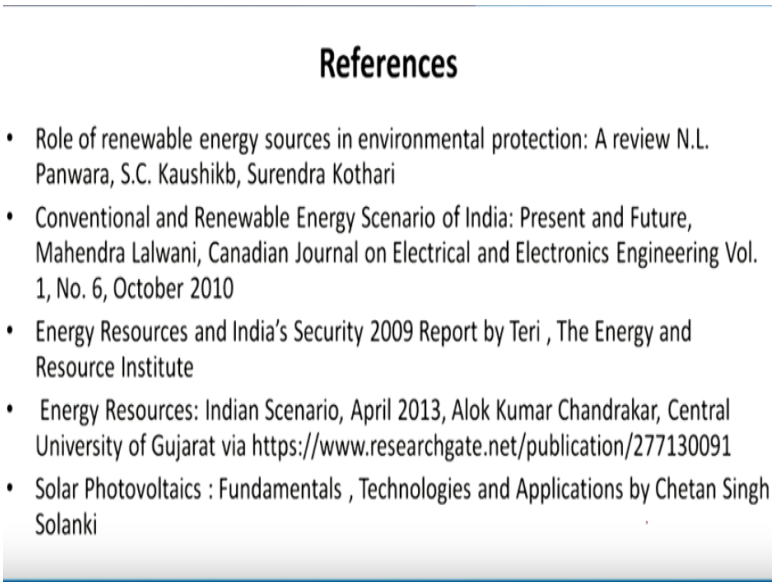


You can find out the details of this text in some of this reference which is mentioned here. So we will stop here in our second module and we will go in the next module how quantum mechanics is going to understand our solar photovoltaic systems. Thank you.