Chemical Process Utilities
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Lecture – 9
Solar Energy-I

Welcome to the next lecture on solar energy. We are discussing the various types of heat transfer media or heat transfer fluid. Under the heat transfer media or fluid, you can see the wide application in the solar panel. When we go for this solar panel anatomy, we need to go a small amount of knowledgeable approach with respect to solar energy. So, in this particular lecture, we will discuss some of the small concepts of solar energy.

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There are two major topics we will cover: the introduction to solar energy and then the different types of parabolic trough collectors or PTC and the linear fresnel reflectors LFR.

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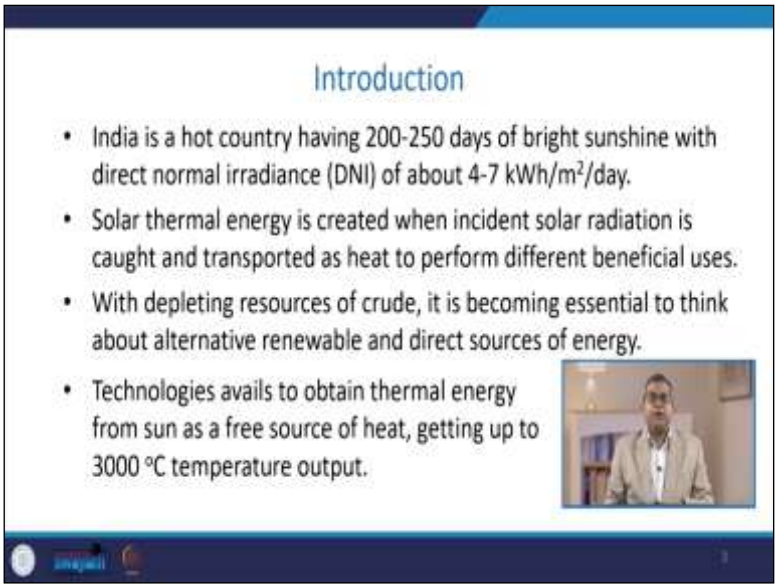

See that India is a relatively hot country, and we have very good opportunities attributed to solar energy. Usually, in the Indian context, we do have 200 to 250 days of bright sunshine with normal, you can say direct normal irradiance of about four to seven-kilowatt hour per meter square per day, which means a huge opportunity huge avenues with respect to the solar energy.

Solar thermal energy is usually created when the incident solar radiation is caught and transported as heat to perform different beneficial uses. With the depleting resources of crude sometimes it is a very challenging aspect, and that is why various government organizations are giving more and more importance or impetus to the use of some alternative energy sources, and solar energy is one of the best candidates.

So, while we consider the things that the crude or natural resources are depleting, it becomes essential to think about various alternative renewable or direct sources of energy or, above all, low-cost energy. Technologies avail to obtain thermal energy from the sun as a free source of heat, getting up to 3000 degree Celsius temperature output, and solar energy is available in abundance.

See when we see a lot of opportunities avenues quantum etc. So, the obtained energy can be utilized in various applications, including water and air heating, preheating, cooking, distillation, food processing etc. Furthermore, a new concept of green building is coming up. For past decades past couple of decades, various regulatory bodies have been

introducing this kind of concept basic objective of this particular concept is to have self-energy sustainable buildings.

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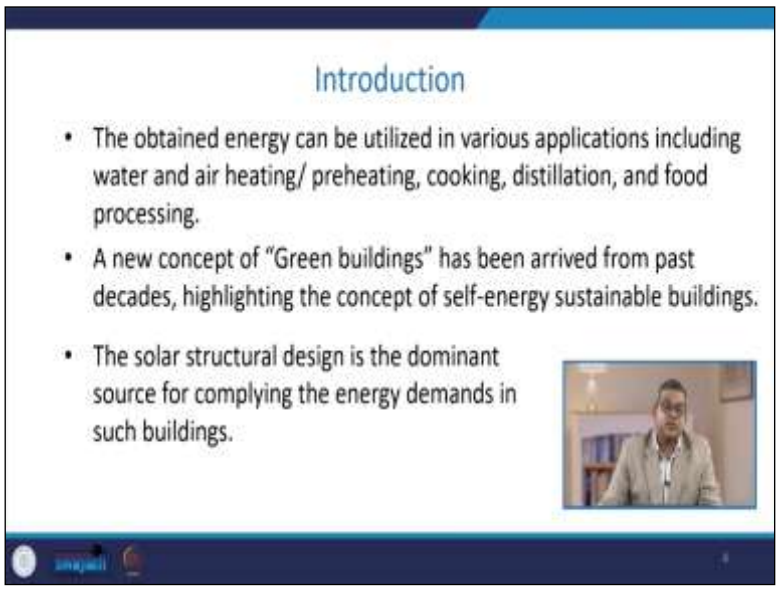

So, the solar structural design is the dominant source of complying with the energy demand in such buildings. The national institute of solar energy has an estimated country's solar potential to be 748 gigawatts, assuming that solar photovoltaic modules cover three percent of the wasteland area. So, you can analyze and imagine how much potential we do have with respect to solar energy.

Solar energy has been prioritized in India's national action plan on climate change with the national solar mission being one of the primary missions. So, keeping in view of this particular fact, a lot of revenues low-cost availability etc. January 11, 2010 the national solar mission was started.

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The national sustainable development mission is a significant project of the Government of India with strong participation from states to promote ecologically sustainable growth while addressing India's energy security issues. Sometimes, it would also be a significant contribution by India to the global effort to address climate change concerns. The mission's goal is to position India as a global leader because of the avenue because of solar energy opportunities by quickly establishing regulatory conditions for solar technology dissemination across the country.

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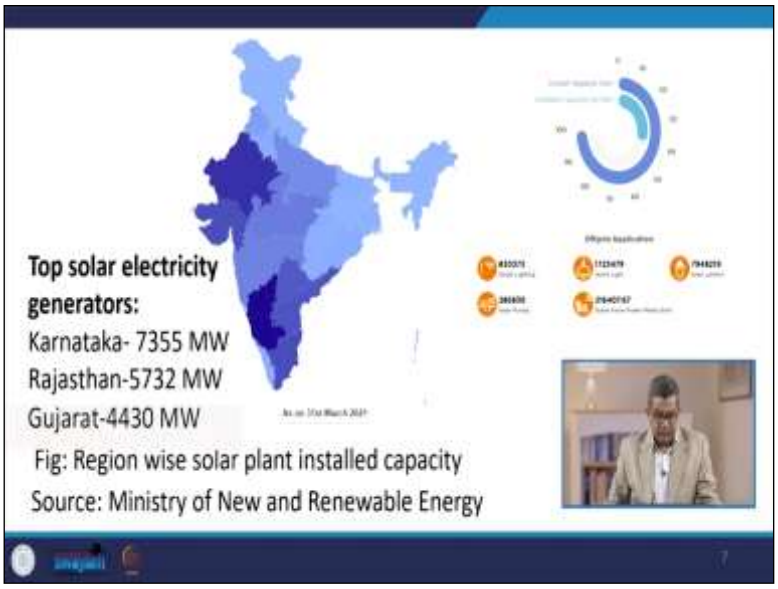

Here you see some of the statistical information. As on March 31st 2021 these are the top solar electricity generators Karnataka 7 355 megawatts, Rajasthan 5732 megawatts, Gujarat 4430 megawatts. The figure shows the region-wise solar plant installed capacity, and the reference is the ministry of new and renewable energy.

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When we talk about the potential of solar power generation, the question arises: how can we classify all these solar power generation technologies. So, the solar-associated power generation technology can be broadly divided into two categories: solar photovoltaic power, i.e., PV, then concentrated solar power, a CSP. So, solar photovoltaics work on the photoelectric effect to convert solar energy into electrical energy directly into electricity.

On the other hand, the concentrated solar power system it works on the principle of light heat electricity conversion.

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The absorbed heat, whatever is absorbed through the sun, is first utilized to produce steam using a solar collector. The produced steam drives the turbine to generate electricity. Solar

photovoltaic is a well-studied field, but it contains some unresolved technical issues. The photovoltaic panels used in such a system pose environmental concerns associated with their manufacturing and recycling steps.

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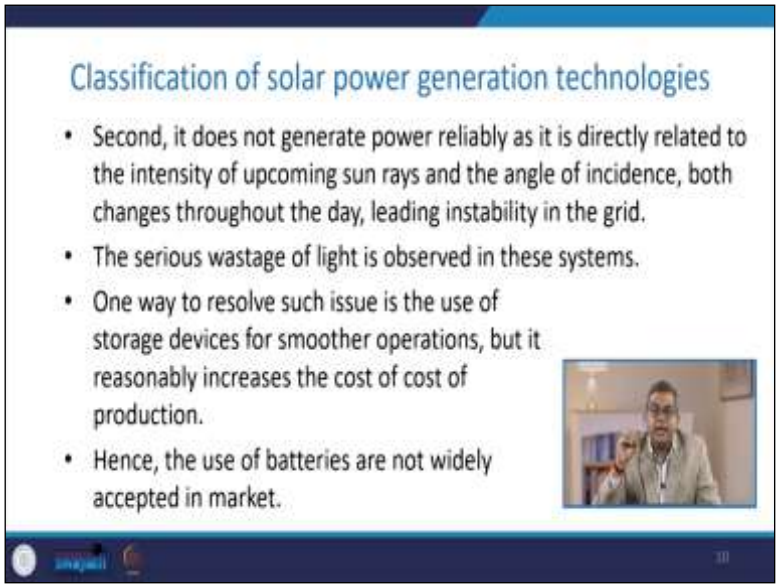

Second, it does not generate power reliability as it is directly related to the intensity of upcoming sun rays and the angle of incidence—both change throughout the day, leading to instability in the grid. In the morning, the intensity of the solar radiation may be on the lower side, and then it may be peaked during the middle of the day. And during the evening it gradually goes down and similarly the direction because sun usually moves in a different direction.

So, it creates a lot of instability. The serious wastage of light is observed in various systems one way is to resolve such an issue is the use of storage devices for a smoother operation. But when we are using the storage devices, we have the storage batteries, which reasonably increases the cost of production. Therefore the use of batteries is not widely accepted in the market nowadays.

Concentrated solar power can overcome these limitations providing a stable electricity generation system with minimal harm to the environment. The use of a costlier battery is also not required due to its unique heat storage assembly and auxiliary electricity generation parts it integrates the energy storage and electricity generation within the system.

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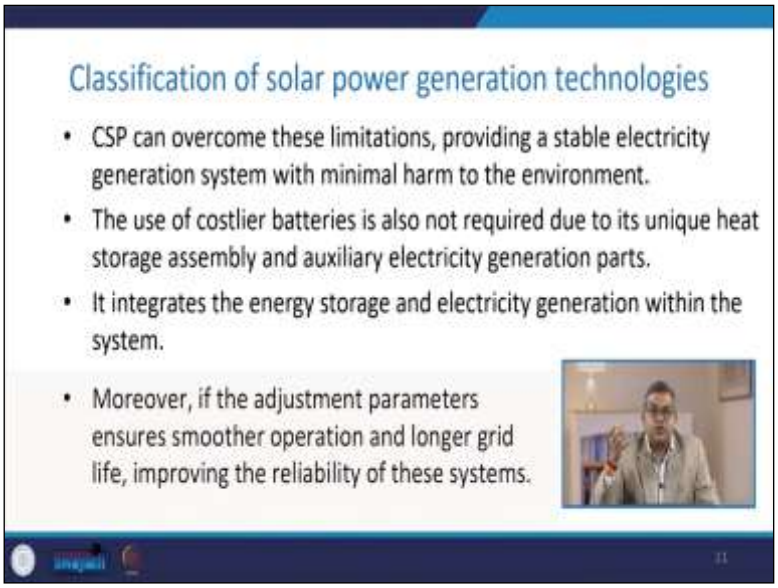

Moreover, the adjustment pattern ensures smoother operation and longer grid life, thereby improving the reliability of these systems.

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In the future, the CSP can help improve power generation through free and green sun energy, helping reduce the carbon footprint. The adoption of this CSP seems challenging mostly because of the higher cost compared to the other resources, one of the resources solar photovoltaic system. Let us discuss the different types of CSP's.

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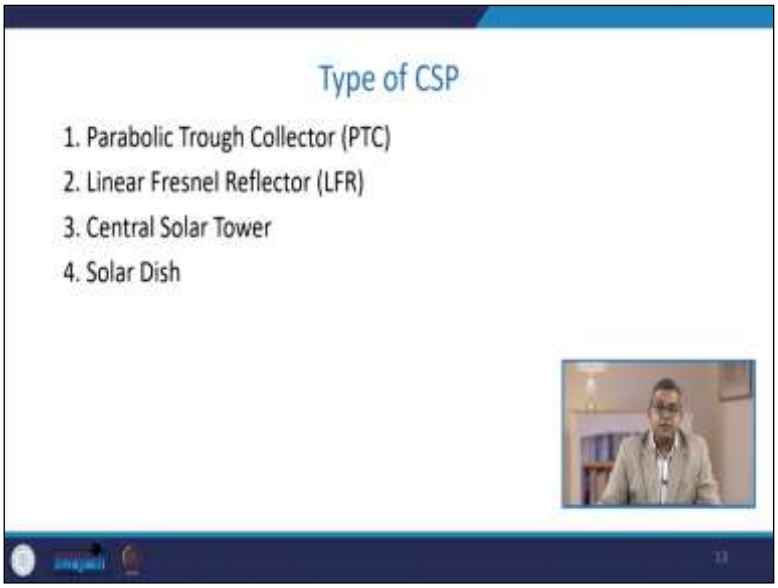

One is the parabolic trough collectors (PTC), then linear Fresnel reflectors (LFR), then central solar tower, and solar dish.

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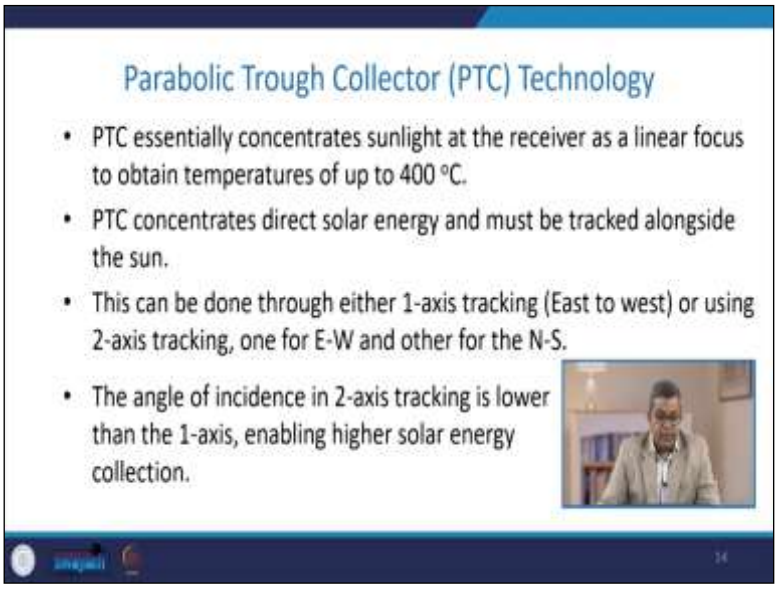

So, first is the parabolic trough collectors technology PTC. The PTC essentially concentrates sunlight at the receiver as a linear focus to obtain a temperature up to 400 degrees Celsius. It concentrates direct solar energy and must be tracked alongside the sun. So, the moment alongside the sun needs to be tracked. This can be done by either one axis tracking east to west or using two excess trackings, one for east to west and the other from north to south.

The angle of incidence in two-axis tracking is lower than one axis enabling higher solar energy concentration.

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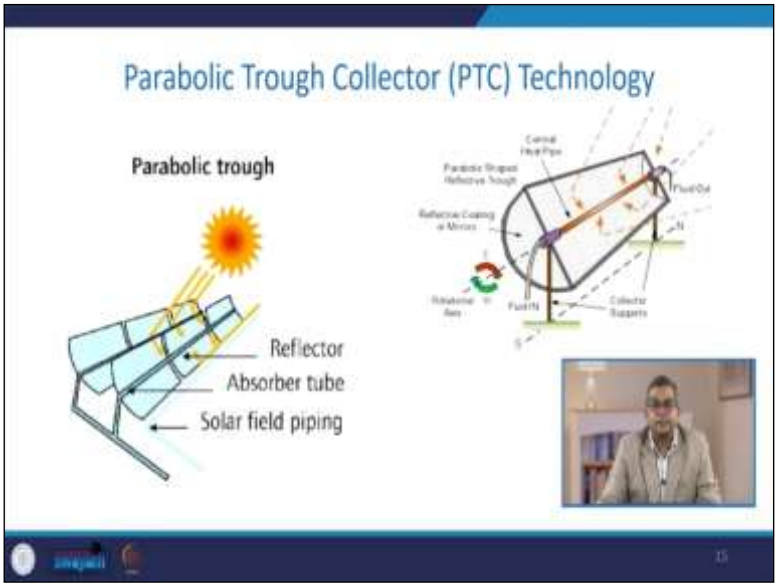

Here you see this parabolic trough. These are the parabolic reflectors, where sun rays impart and get reflected towards the absorber tube. So, these are the reflectors, the absorber tubes, and the solar field piping. Here you see the anatomy of this parabolic shape reflecting trough, this is a central heat pipe you see the reflective coating mirrors, and this is the rotational axis you see that which we are discussing the east to west and north to south and these are the supports.

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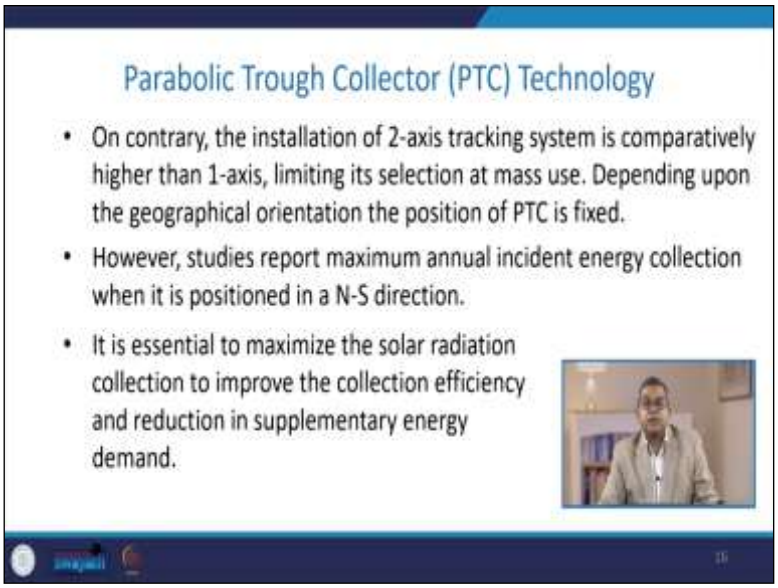

On the contrary, installing a 2-axis tracking system is comparatively higher than one axis, limiting its selection at mass use. Depending upon the geographical orientation, the PTC position can usually be fixed. However, studies report the maximum annual incidence to incident energy collection when it is positioned in the north to south direction.

It is essential to maximize the solar radiation collection to improve the collection efficiency and reduction in supplementary energy demand.

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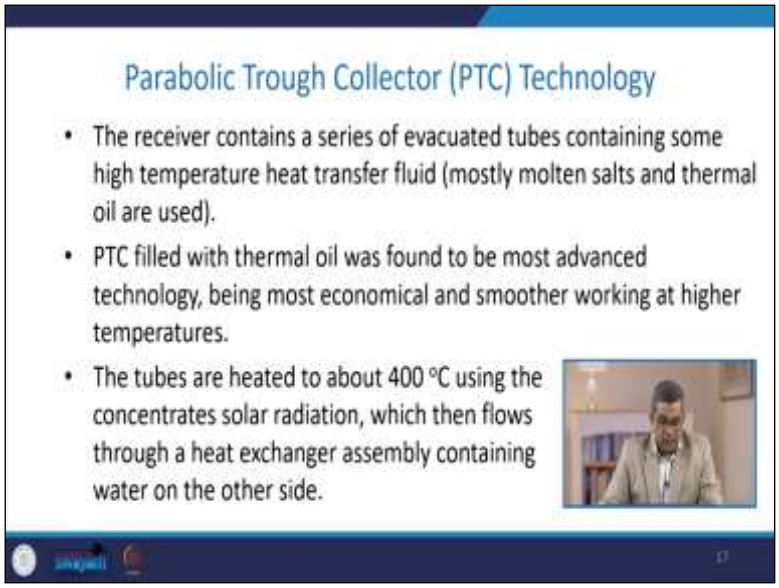

The receiver contains a series of evacuated tubes containing some high-temperature heat transfer fluid. This can be a molten salt, thermal oil, or synthetic oil. Depending on the use and how much heat transfer capacity you require, it can be used. These are filled with thermal oil, the most advanced technology, and the most economical and smoother working at high temperatures.

These tubes are heated to about 400 degrees Celsius using the concentrated solar radiation which then flows through a heat exchanger assembly containing water on the other side. So heat transfer can take place the high pressure superheated steam is thus produced using this particular approach. Whatever steam you produce is then passed through our conventional steam turbine power generator to produce the electricity. So, it is clubbed with the power generation unit.

So, first, the concentration of solar irradiation then heats the thermic fluid and then passes on the absorbed energy or heat to the water to generate the steam, and the steam then used as the power generation plant to the power to generate power or to generate electricity. So, whatever steam is used in the course of time, it can be cooled to the condenser to improve the pumping efficiency on the compression cycle.

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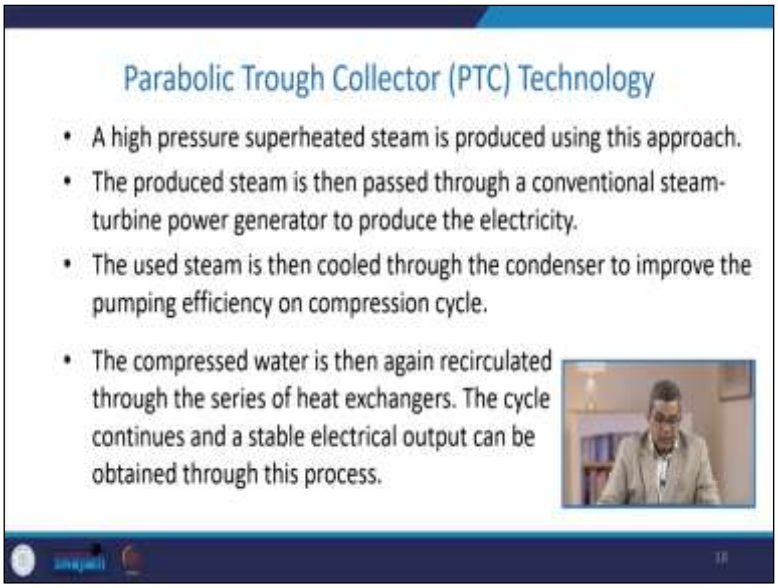

The compressed water is then again recirculated through the heat exchanger series, and the cycle continues and stable electrical output can be obtained through this process.

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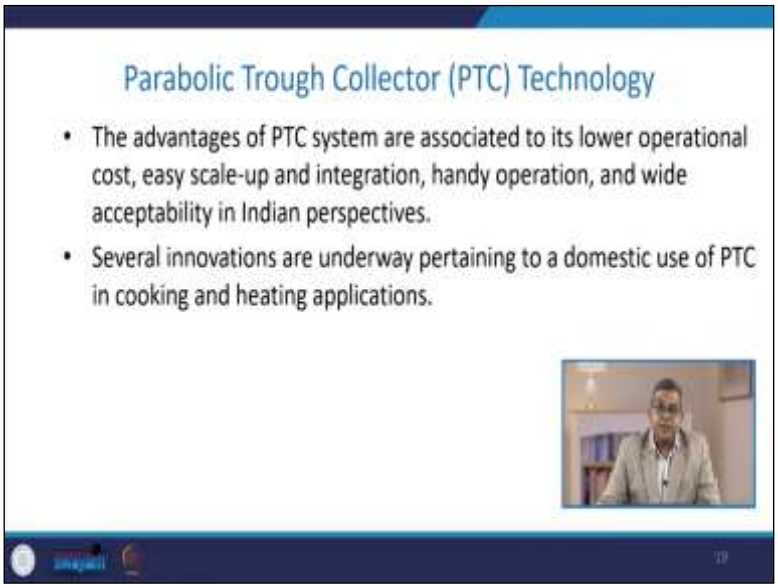

The advantages of this PTC system are associated with its lower operational cost you can easily scale up and integrate it is very handy to operate, and has wider acceptability in a local perspective. Several innovations are still occurring in the domestic use of PTC in cooking and heating applications because a sizeable quantum of energy is being consumed in these two domestic operations.

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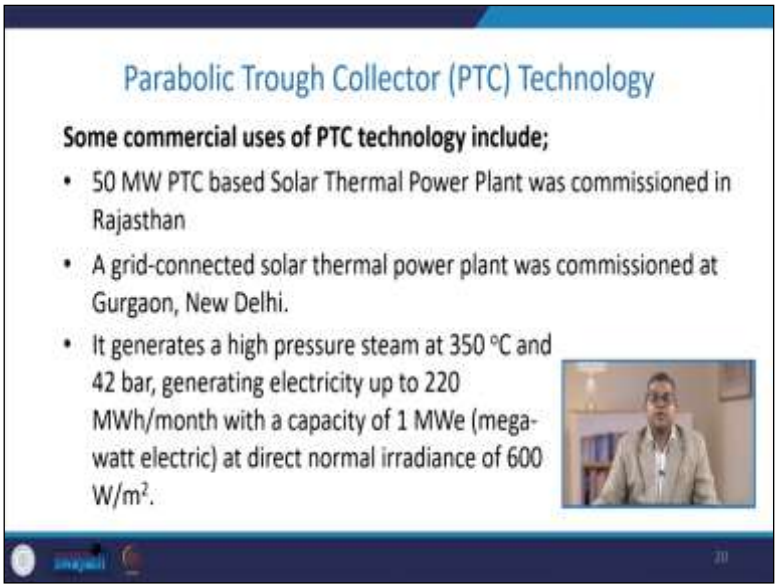

There are some commercial uses of the PTC technology, including the 50 megawatts PTC-based solar thermal power plant commissioned in Rajasthan. A grid-connected solar thermal power plant was commissioned at Gurgaon, New Delhi. Usually generates high-pressure steam at 350 degrees Celsius and 42 bar, and it can generate electricity up to 220 megawatts with a capacity of one megawatt electric at direct normal irradiation of 600 watts per meter square.

Let us discuss the linear fresnel reflectors technology LFR. The term fresnel in the LFR technology comes from the name of a fresnel lens, which consists of multiple reflecting planes which help to enhance the concentration of light coming from different direction in different angles.

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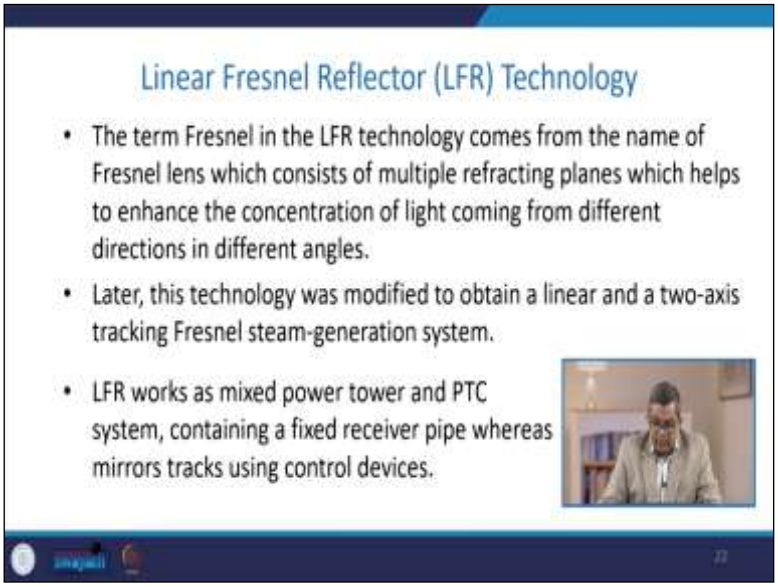

Later on, this technology was modified to obtain a linear and two-axis tracking of the fresnel system, which helped the steam generation system. This LFR works as a mixed power tower and PTC system containing a fixed receiver pipe whereas mirror tracks use control devices.

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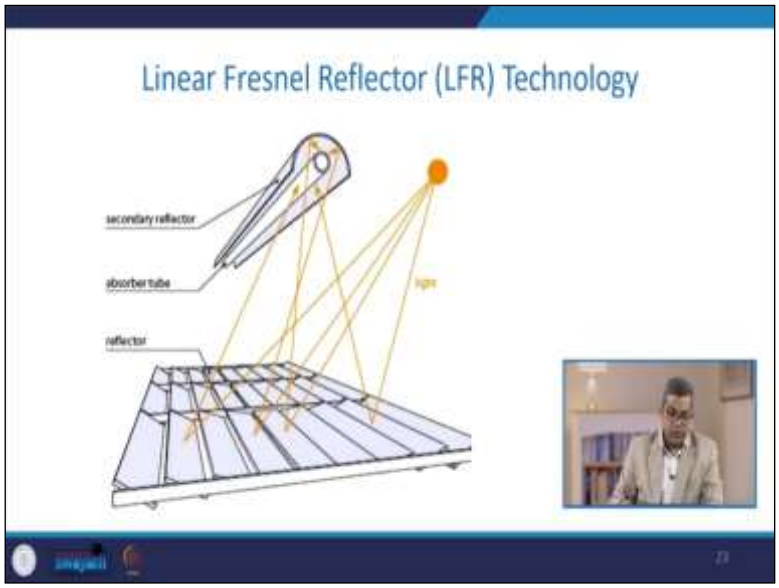

Here you see that these are the LFR technology. We have the reflectors,and there are secondary reflectors which comprises of absorber tubes. So, when light passes on these first-hand reflectors, it goes to these secondary reflectors, and whatever the thermic fluids are there, it can get absorbed the solar energy.

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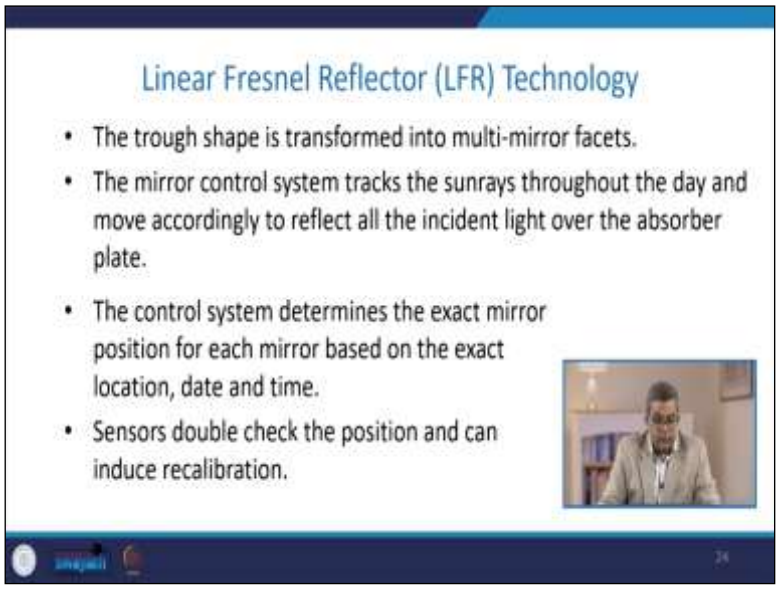

So, this trough surface is transformed into a multi mirror facet. The mirror control system tracks the sun rays throughout the day and moves according to the reflection accordingly

to reflect the incident light over the absorber plate. The control system determines the exact mirror position for each mirror based on the exact location, date, and time. Sensors usually be double check the position and can induce recalibration.

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So, whatever mirrors are being used in this LFR technology are at a different angle as the relative position that is a sun mirror, or absorber tube is different. These mirrors can be flat or slightly curved, reflecting the light trays towards the linear collector containing stainless steel absorber tubes. The collector can be a fixed absorber placed at a common focal line of the reflecting mirror.

The reflectors can have a single or a dual-axis tracker allowing maximum collection of solar radiation in a day. The secondary concentrator is also used to place the rays according to the accepting angle the radiation missing the absorber tube hits the secondary reflector, which again concentrates the radiation on the absorber tube.

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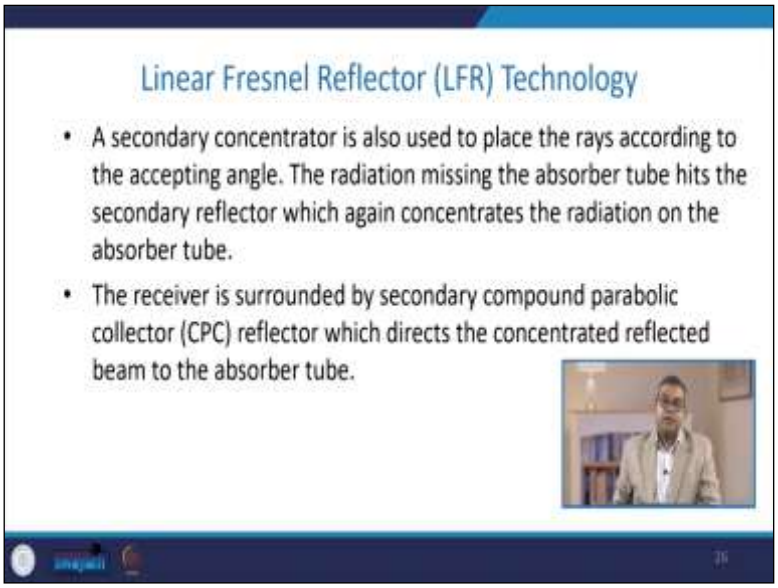

And usually, the receiver is surrounded by a secondary compound parabolic collector (CPC), which directs the concentrated reflected beam to the absorber tube.

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The LFR technology whole system consists of a CPC reflector and receiver with two stainless steel tubes walled in a glass casing. You can see this tube, and this is the glass casing. This unit can be evacuated as the vacuum reduces the heat loss from the absorber pipe. So, these are the absorber pipes, and if you put a vacuum, the heat loss can definitely be minimized.

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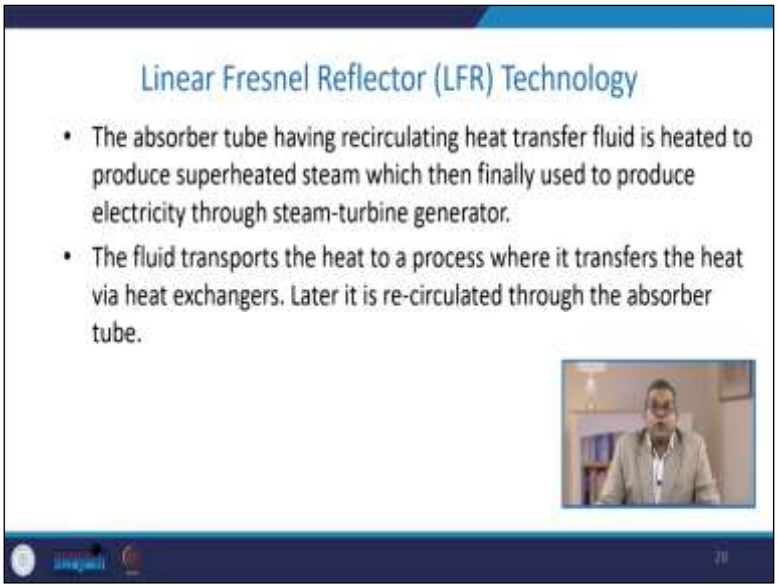

The absorber tube has the recirculating heat transfer fluid, which is heated to produce superheated steam, which is then used to produce electricity through steam turbine generators. The fluid transports the heat to a process where it transfers the heat via heat exchangers, and later it is recirculated through the absorber tube. The modified LFR system allows water to act as a transfer fluid or heat transfer media.

This produces steam as high as 285 degrees Celsius inside the absorber tube, and by this way, you can reduce the cost of additional heat exchanger assembly.

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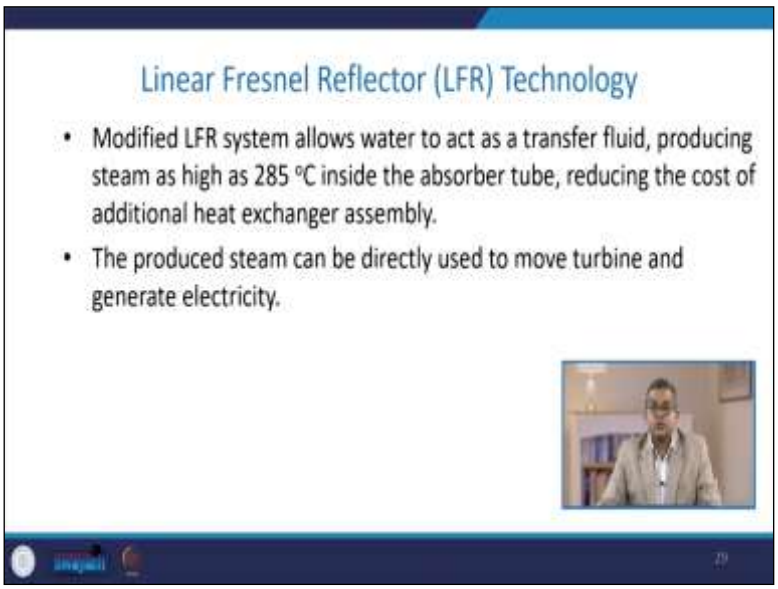

The produced steam can be directly used to move the turbine and generate electricity. So, you may eliminate the requirement of the additional heat exchanger.

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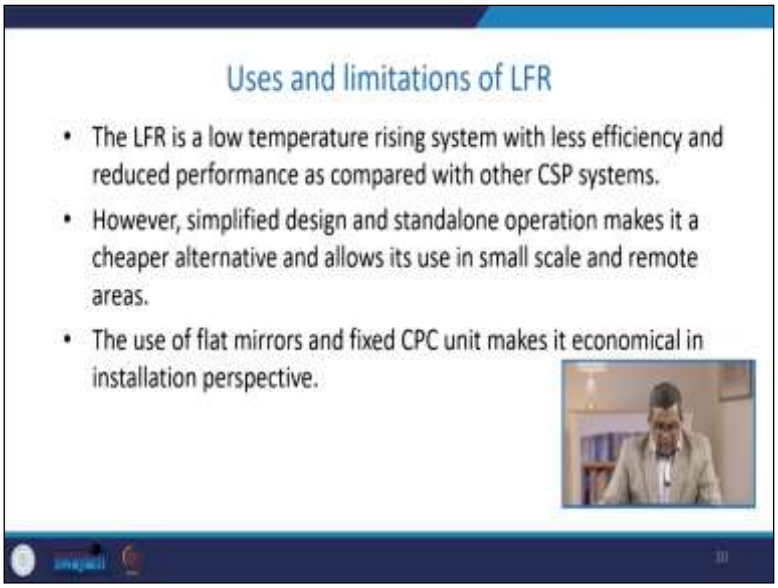

There are certain specific uses and apart from this limitation of LFR. This LFR is a low-temperature rising system with less efficiency and reduced performance as compared to other CSP systems. Simplified design and standalone operation make it a good candidate because it is a cheaper alternative and allows its use in small-scale and remote areas. The use of flat mirrors and fixed CPC units make it more economical from the installation perspective. So, it is economically feasible in this respect.

It also provides the enhanced land consumption then linear to, and a power tower system, and it can be combined with the working of a fossil fuel production system for energy generation throughout the day.

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There is neither a vacuum no matter glass sealing requirement in LFR, and also due to the reduced wind load on the reflector plate, its width can be increased to about three times as compared to the parabolic row. However, we have other technologies. So, when compared with the PTC technology, the power per unit of land area in LFR is smaller. Therefore, it opens a new avenue because it offers more revenue for the research and more research is needed in this field to utilize more areas, such as the reason beneath the collector.

The industry is a significant energy user, especially the chemical industry accounting for over 30 of the total final energy consumption process heat accounts for approximately 67% of overall industrial energy consumption. Sometimes a significant portion, approximately, you can say 57% of the total process heat demand is in the medium temperature range, that is around 400 degrees Celsius.

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And maybe met using this LFR technology.

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Industrial processes process heating is usually a major consumer of heat energy usually are typically provided using heat exchangers from a distribution grid, allowing uncontacted heat transfer with sustained purity. Steam is the most common heat transport fluid used in this particular industry. The industrially adopted LFR collector many directly created create saturated or superheated steam, and thereby it can be used in the steam power generation plant.

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Thermal oil or pressurized water can also be utilized as a heat transfer fluid, and both are well suited for integration into solar process heat solution. So, solar cooling solutions are also available to compensate for the cooling requirement. Similarly, when we talk about the direct normal irradiation which is greater than 1500 kilowatt-hour per meter square at

the best suitable for solar process heat application using the industrial solar phenol collector technology.

So, at the outset, we discussed the solar energy different types of solar system solar energy production systems being used.

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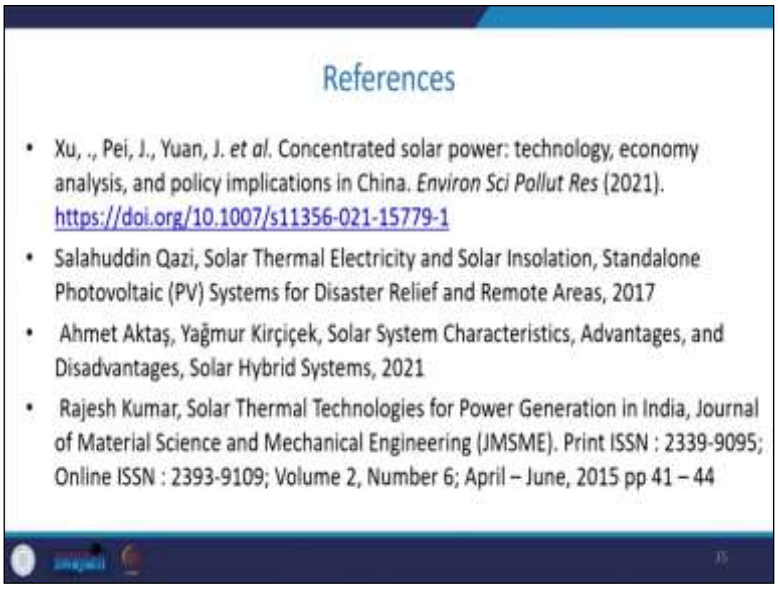

For convenience, we have enlisted for references. Further reading is needed then you can have a look at these references, thank you very much.