Renewable Energy Engineering: Solar, Wind and Biomass Energy systems

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Lecture – 14
Solar Energy Utilization Methods

Hi everyone today in renewable energy engineering solar wind and biomass energy system we are going to discuss about solar energy utilization methods in lecture 8. In this lecture, if we see what are all the other solar utilization methodologies, already we have discussed direct solar thermal conversion, there is another direct conversion technique which is nothing but solar energy into directly electricity which is nothing but photovoltaic option, but we are not going to discuss in this course about solar PV.

So, we skipped that part in solar direct conversion and an indirect conversion, wind and biomass we are going to discuss in this course, so, this lecture would be of very short lecture about other solar utilization methods. In this lecture, we are going to discuss about other solar utilization methods which are nothing but wind and biomass energy system. There are other indirect solar conversion, but we are not going to concentrate on them.

So, here in this lecture basically we are introducing other solar utilization methods which are nothing but wind and biomass energy system. Before going into that, we extensively discussed about the solar thermal conversion how to get solar radiation parameters and how to collect in non-concentrating and concentrating collectors. And if there is an off-sunshine hours, how do I store the solar energy and what is the industrial aspect for solar energy that first we will discuss, after that we will discuss about indirect solar conversion techniques, which are nothing but wind and biomass energy system.

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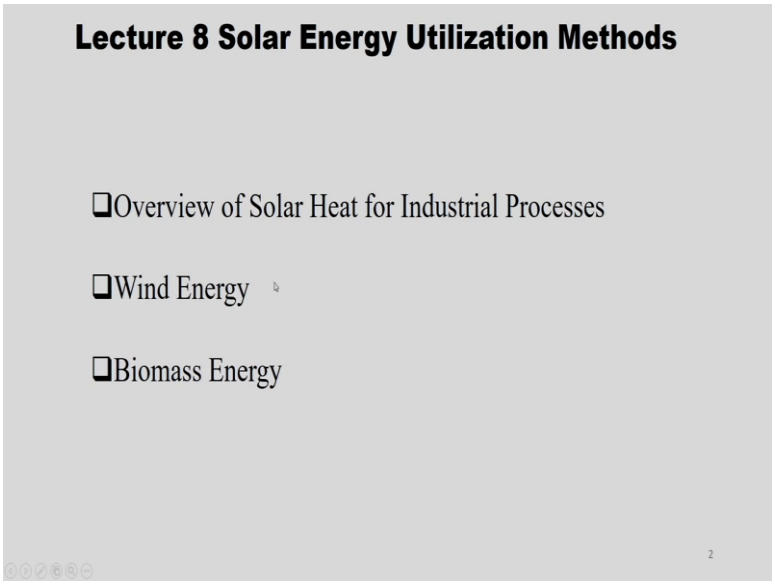

This lecture is going to be outlined in this way overview of solar heat for industrial processes wind energy and biomass energy.

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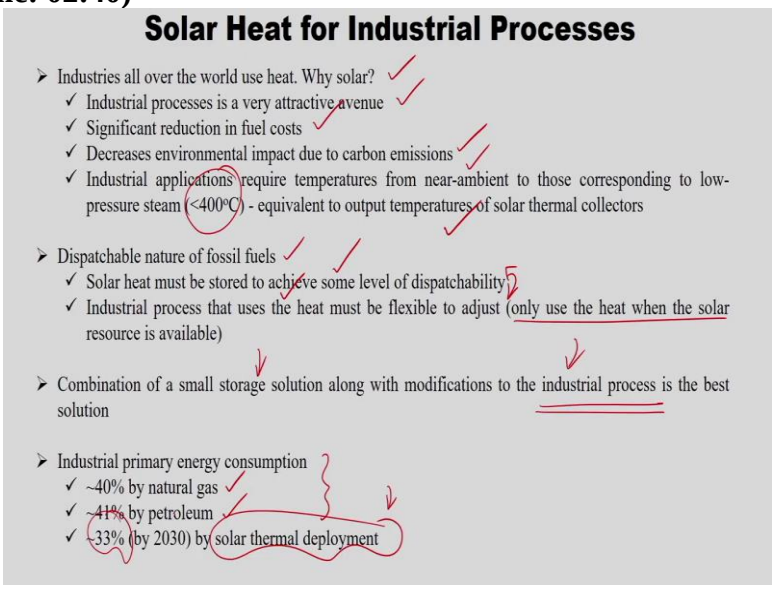

First one we are going to discuss about solar heat for industrial processes, industries all over the world use heat whether the heat comes from fossil fuels or solar that does not matter, but they want heat. Industrial process is a very attractive avenue for solar energy as a heat significant reduction in fuel costs, because industry need not pay anything for fuel if they are comfortable in using solar energy for their heat requirement.

It also decreases environmental impact due to carbon emissions. So, there is no carbon emissions and solar energy. So, in that way environmental impact also gets decreased industrial applications requires temperature from near ambient to those corresponding to low pressure steam, which is about less than 400 degrees centigrade, this particular range of

industrial requirement perfectly matches with the output temperatures of solar thermal collectors.

So, that is the way the solar is a very attractive option for all industrial requirements. The another, thing we need to concentrate here is the dispatchable nature of fossil fuels. Solar heat must be stored to achieve some level of dispatchability that is not the case in fossil fuels, because the solar is coming from nature. So, we are depend on its level of dispatchability. The industrial process must be flexible to adjust to this dispatchability level of the solar energy only use the heat when the solar resources available.

There heat requirement should be able to match. So, these 2 are interconnected either the solar heat we need to store and use it for throughout the industrial operations or the industrial operations should be able to match the dispatchability level of the solar energy are sometimes the combination of both can be done combination of a small storage solution along with modifications to the industrial processes is the best to solution.

Because if I require heat for 8 hours only 8 hours, if I am able to produce solar energy heat around 6 hours, then 2 hours I may go for storage solar energy storage. So, this combination of both so, in a way the industrial process also modified to get only 12 hours or 11 hours of heat requirement and remaining 1 or 2 hours, we can use some small storage solution, we already learned the more we store the energy more would be losses as well.

So, to reduce the storage period in shorter there may be adjustments between industrial processes and solar energy requirement. So, industrial primary energy consumption, are from natural gas which is around 40% from petroleum which is around 41% and researchers are working or there is a goal which sets solar thermal deployment of about 33% in industrial sector by 2030.

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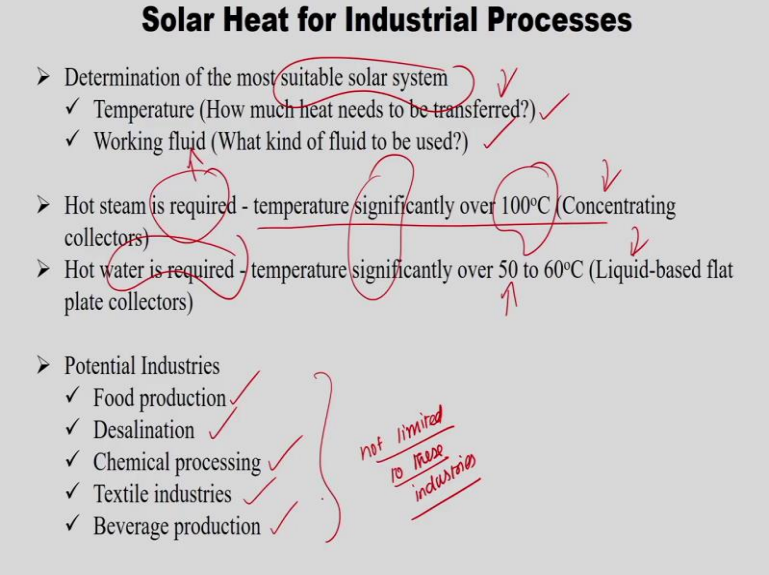

When we are interested in solar energy system for all industrial heat requirement, there are 2 things we need to be worry about or we need to be careful about the one is the temperature. So, the how much heat needs to be transferred to meet the temperature requirement of the particular industrial process. The second one is what kind of fluid to be used as a working fluid to meet the temperature requirement, if hot steam is required, then that temperature significantly over 100 degree centigrade.

So, concentrating collectors would be able to provide that or if hot water is required the temperatures significantly over 50 to 60 degrees centigrade. So, liquid based flat plate collectors whatever we discussed may be of use. So, even if you want to produce these 100 degrees centigrade, instead of going for concentrating collectors, you may even try vacuum tubes or you may even try with some other fluid whether you would be able to provide that 100 degree centigrade heat even with a flat plate collector module.

So, that research can be of much useful if you want to use your solar heat for industrial processes, the potential industries for solar energy utilization or food production, desalination, chemical processing, textile industries, beverage production, but they are not limited to these industries. Because this is given here based on the applications what we discussed input production normally you would be using solar dryers.

Drying equipment, desalination solar stills can be of use and chemical processing, you can still use solar energy system and textile industry, there may be a requirement for drying in

beverage production also wherever the heat requirement is needed, that can be provided by solar energy as an option wherever you needed the heat that can be provided by solar energy.

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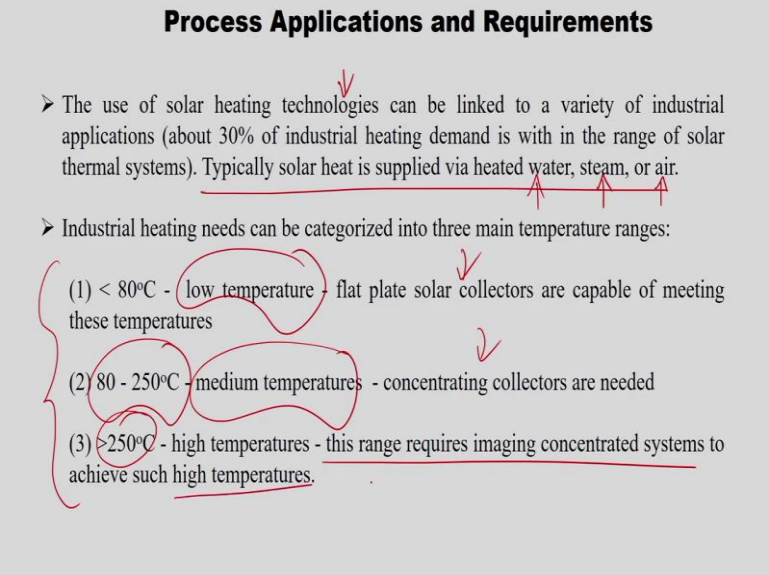

Then process applications and requirements. So, based on the solar heating technologies, which can be linked to a variety of industrial applications, they can be divided into 3 main categories. So, typically solar heat is applied via hot water, steam or air. So, this is what we said solar heaters. This is liquid flat plate collector or any concentrating collectors will provide the steam.

So, there are 3 categories one is low temperature application which requires less than 80 degree centigrade temperature. So, flat plate collectors are capable of meeting these temperature 80 to 250 degrees centigrade, which is medium temperatures, concentrating collectors are needed to meet this requirement, then high temperature applications are greater than 250 degrees centigrade, this particular range requires imaging concentrated system to achieve such a high temperature. This we have discussed already in concentrating collectors.

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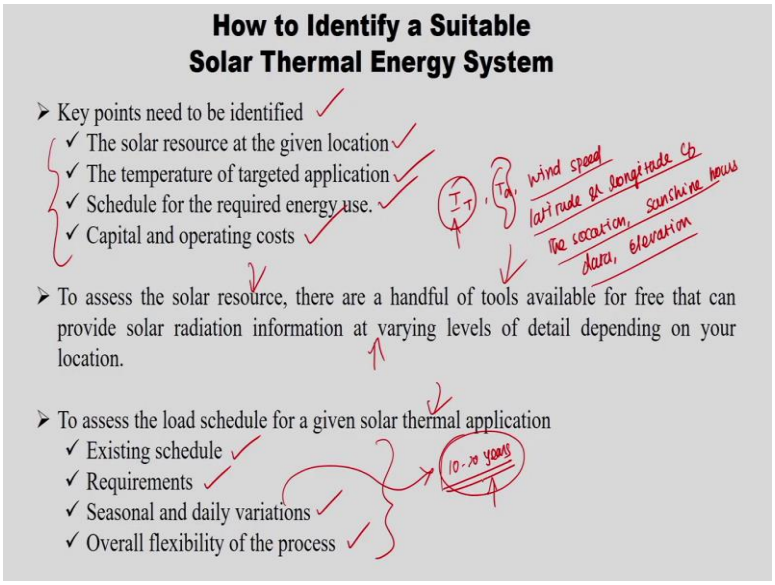

How to identify a suitable solar thermal energy system for industrial requirements. The key points to be identified are the solar resources at the given location. So, first thing we would require is that for the given location what is the solar resources. So, how much I T will be able to gain at that particular location. Second one is temperature of the targeted application which industrial application or which industrial process, you would like to use solar energy heat as an option.

The third one is scheduled for the required energy use, if there is off sunshine hours what I would be doing or whether any modifications in the industrial processes can be done to match the on sunshine hours of the solar energy and then capital and operating costs as we said earlier, the solar energy the initial capital costs are very much high compared to operating costs. So, this economic analysis also one need to keep in mind when you think solar thermal energy system as an option for any industrial processes.

To access solar resources, there are a handful of tools available for free that can provide solar radiation information at varying levels of detail depending on your location. What we would be requiring? I T, then ambient temperature then ambient wind speed then latitude and longitude of the location then sunshine hours data then elevation of the length particular location etcetera.

So, for this we can depend on either experimental method or the numerical correlations whatever we learned and this can be done by any temperature sensor and for this one can get it from some meteorological data from the particular location and also, we extensively

discussed about this. So, how to calculate the main radiation parameters using available sources.

So, sometimes we are given local apparent time sometimes we were given in Indian Standard Time, sometimes we were given the extra-terrestrial radiation parameters and how to get them for clear sky so, extra. So, whatever is available with you can do or you can calculate the solar resources for that particular location either by experimental or by numerical methods are by using empirical correlations and to access the load schedule for a given solar thermal application.

The existing schedule requirements and seasonal and daily variations and overall flexibility of the process all are required. So, the moment we say seasonal and daily variation here also, there is an important point to mention for example, you are designing a space heating for a building. So, there you would be requiring the solar radiation data since it is a natural resource.

So, we may not be able to design particular space heating solution for a building with just available with 1 year data or 1 month data. So, we would be requiring at least to some 10 to 20 years data to see how this is changing. So, it is not always the summer extends for this many months are the winter period is for this many months we will not be able to accurately predict. So, it is an approximate data, but if you as long as you get more number of years, when you are seeing the trend of the variation that much you would be able to accurately the near accurate you would be able to predict the seasonal and daily variations.

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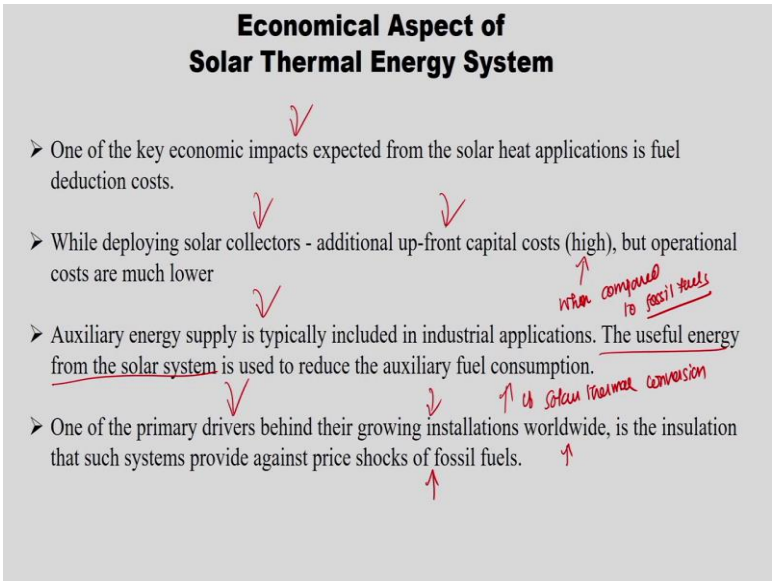

And then economical aspect of solar thermal energy system. So, here as I said earlier, it is not only the aspects what you learn the conversion technologies, but whether it is economically feasible as we discussed in the introduction lecture, it is not only the systems and because if you see there are various conversion technologies are there. So, flat plate collectors are there concentrating collectors or they are not concentrating collectors are there.

Whether one need to go for thermal energy storage or not, whether making modifications in the industrial process would be feasible or having a thermal energy storage solution would be feasible. So, extra are the with many technologies with the many requirements based on my requirements with many technologies, so how do I be able to choose particular things energy solar thermal energy solution for a particular industrial process there comes the economical aspect.

One of the key economic impacts expected from the solar heat applications is fuel detection cost because, while deploying solar collectors there are additional upfront capital costs which is usually higher when compared to fossil fuels. But operational costs are much lower compared to other fossil fuel thermal energy systems in any industry, they typically include the auxiliary energy supplied.

So, but the useful energy from the solar system is used to reduce such kind of auxiliary fuel consumption in any industrial processes. One of the primary drivers behind their growing installation worldwide of growing installation of solar thermal conversions is the insulation that such systems provide against price shocks of fossil fuels. So, here you are not paying

anything for fuel, we agree that there is a collection and storage for that we need to spend a lot of initial investments as a capital cost.

But the thing is this variation in the price of the fuel one need not worry about that price shocks of fuel that is there for fossil fuel which is not there for solar energy. So, that is where this attracted many avenues in industrial processes.

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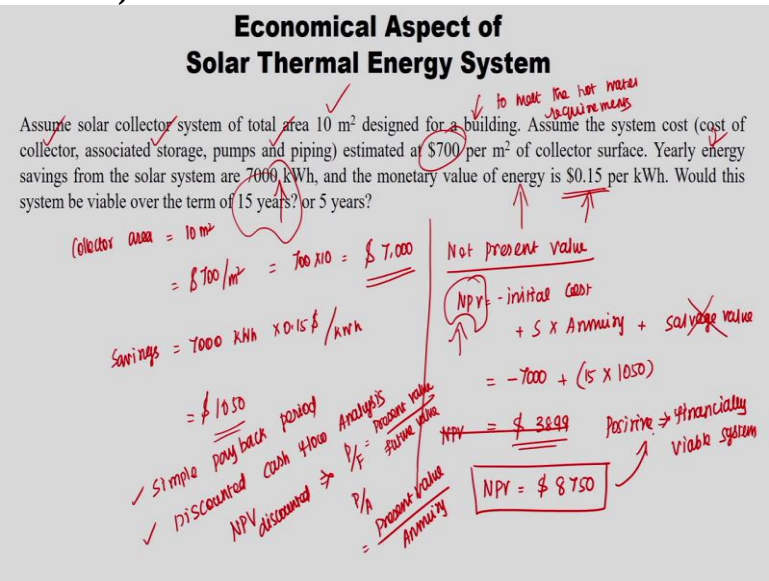

So, here we are going to analyse simply about one particular solar collector system. So, we are not experts in economical aspects to analyse in depth however, based on the based on certain formula and payback period, so, we will analyse whether that particular system or particular project you will be choosing is financially viable or not. Here it is given solar system of total area 10 meters square is designed for a building probably to meet the hot water requirements.

Assume the system cost which includes collector cost associated storage pumps and piping etcetera is estimated to be 700 dollars per meter square of the collector surface yearly energy savings from the solar system are 7000 kilowatt hour and monetary value of energy is 0.15 dollars per kilowatt hour would the system be viable over the term of 15 years or 5 years. So, this we are going to check.

So, the collector area is given as 10 meters square and it is said that the system cost is around 700 dollar per meter square. So, 700 into 10 which is about 7,000 dollars. This is the capital costs and yearly savings we are getting around 7000 savings is 7000 kilowatt hour, but the

monetary value is 0.15 dollars per kilowatt hour. So, if you calculate 7000 into 0.15. So, what you would be getting is 1050 dollars.

So, this is your annuity because what is this monetary value if you are not having the solar energy system you would be paying around 0.15 per kilowatt hour for the electrical heating of your hot water requirement. So, now, we need to analyse whether the system would be viable over the period of 5 years or 15 years or 10 years. So, I will do it for 15 years I will give you this, 5 years to check whether it is feasible or not as a home task for you.

In such analysis there are in depth analysis to do for such a system, but here we are going to use the net present value concept. So, which is defined as NPV is defined as initial cost which is minus plus number of years into annuity plus salvage value. So, here in this problem there is no salvage value given. So, we assumed there is no salvage value. So, the initial cost we have calculated as 7000 plus number of years we are going to take first 15 and annuity how much hour we calculated?

How much we calculated as 1,050 dollars. So, if you calculate it is coming around 3899 dollars. So, if this net present value is coming as positive then we can say the system as a financially viable system, what is this net present value? So, normally for any system what we say is the present value is more when compared to the future value the future one because due to inflation rate.

So, based on this net present value we can analyse whether that particular project is financially viable or not. So, if you want more, there are 2 simple analysis one is simple payback period. So, this net present value is based on SPB and there is another analysis which is called discounted cash flow analysis. So, if you want to calculate NPV based on discounted cash flow analysis, this is nothing but the NPV discounted there we would require 2 factors one is P upon F of another is P upon A. So, what is P? P is nothing but present value upon future value P upon A this is nothing but present value upon annuity.

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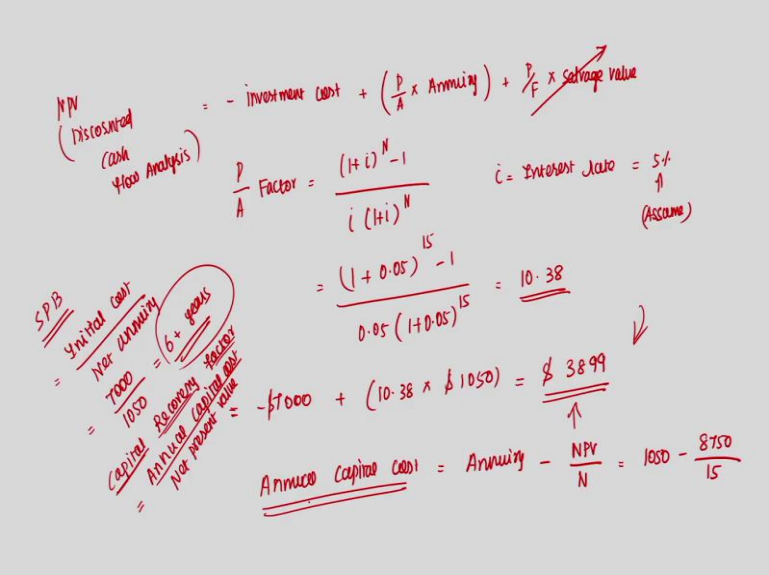

So, if you want to calculate the NPV in terms of discounted cash flow analysis they said that minus investment cost + P upon A into annuity + P upon F into salvage value this we are not going into take into account. So, what is this P upon A factor. So, this is defined as 1 + i to the power N -1 upon i into 1 + i power N. So, what is i? i is nothing but interest rate. If you assume this is 5%. So then 1 + 0.05 we are calculating for 15 years – 1 0.05 1 + 0.05 whole to the power 15.

So, this is coming as 10.37 or we can take it 10.38. So, if you calculate - 7,000 + 10.38 into 1050. So, which is coming around 3899. This is NPV value is -7000 + 15 into 1050 this is coming around 8750. Since it is positive the system is financially viable system. So, here also your NPV is positive. So, this system is financially viable system. So, whether you go by discounted cash flow analysis or you go by the simple payback period analysis both the NPV is positive.

So, the system is financially viable system and there are certain definitions related to that which are nothing but the SPB, simple payback period which is equivalent to initial cost upon net annuity. So, initial cost here is 7000 upon net annuity is nothing but 1050. So, if you calculate this then you would be getting 6 + years. So, that means, when you are doing home task around 5 years you might be getting NP value as minus.

Because the minimum payback period itself coming as 6 + years and there are several more definitions which is nothing but capital recovery factor which is nothing but annual capital cost upon net present value. You have net present value you can calculate capital recovery

factor. So, what is the annual capital cost which is nothing but annuity minus net present value upon number of years.

So, you have annuity 1050 you have net present value if you are using SPB analysis, it is 8750 number of years you calculated is 15 from this you can calculate annual capital cost if you know annual capital cost by using NPV, net present value you can calculate capital recovery factor as well. So, this is a simple analysis we have not detailly we discussed how we arrived at this formula, but it is just to introduce you the economic analysis it is not that when you propose a project the industry would okay it.

For them the payback period is most important if they invest something then how much how quickly they would be able to get the profit just to introduce you we have done this analysis you can refer the fourth reference given in this particular lecture to get to know about more of economic analysis.

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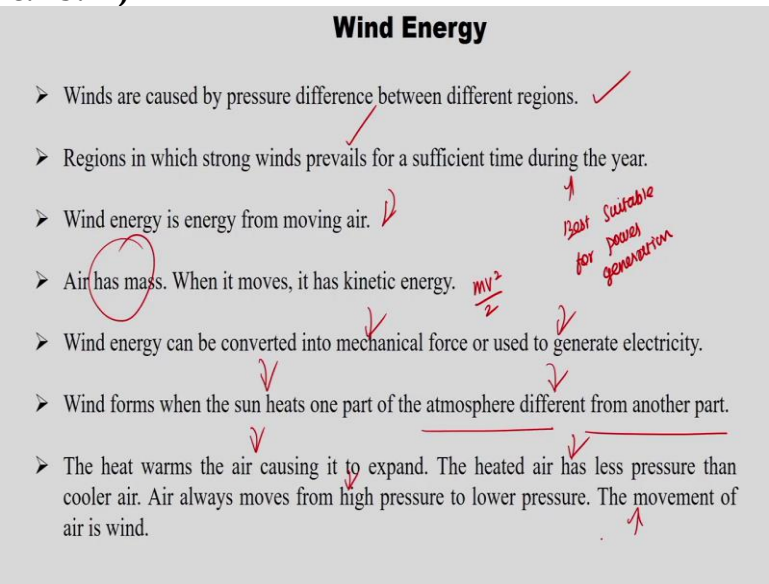

The next one is wind energy winds are caused by pressure difference between different regions. The regions in which strong wind prevails for a sufficient time during the year. They are best suitable for power generation. Wind Energy is nothing but energy from moving air. So, air has particular mass when it moves it has kinetic energy, which is nothing but half mv square.

Wind energy can be converted into mechanical force or they can be used to generate electricity as well wind forms when the sun heats one part of the atmosphere different from

another, this is what we might have told an introduction lecture itself, the solar is the cause for creating a wind if one part is getting heated largely compared to other part, then wind forms. The heat warms the air and causing it to expand and the heated air has less pressure than the cooler air. So, air always moves from higher pressure to lower pressure that is the moment of air, which is nothing but wind.

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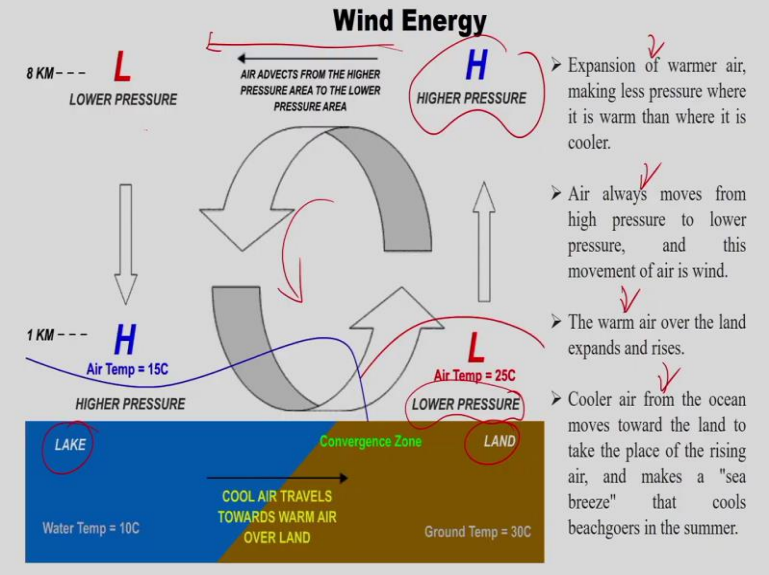

So, this diagram shows how the process is happening, the expansion of warmer air making less pressure where it is warm, then where it is cooler. So, if you see this is the lake side and this is the land side the sun heats land side more the temperature also increases. So, when the temperature increases this becomes the low-pressure zone then from high pressure zone the air started moving to low pressure zone that is the way the pressure differences create the air motion which is nothing but wind.

So, air always moves from higher pressure to lower pressure and this movement of air is nothing but wind the warm the air over the land expands and rises, the cooler air from the ocean moves toward the land to take place of the rising air and makes a sea breeze that cools the beachgoers in the summer. So, this is what the basic working principle how the wind energy is created, there the high-pressure wind is created high pressure air moment has created.

So, this air advects from the higher-pressure area to lower pressure area because when you go high in altitude, so this becomes lower pressure then it moves to this high-pressure air moves to the side. So, this is the way convection current is created it is basically the air moves from

higher pressure to lower pressure. Lower pressure how it is created? It is created by the sun which heats the particular location more compared to other location. This process continues and the wind is formed it is not only in the land side and lakeside.

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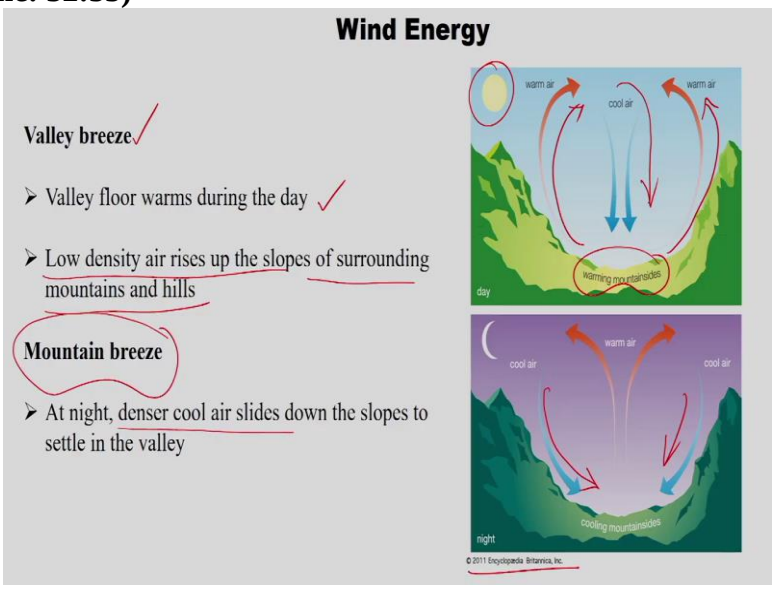

This happens in the valley and mountain side as well. If you see here the warming up mountainside in the daytime. Daytime what happens is the valley floor warms during the day and the low-density air rises up the slopes of the surrounding mountains and hills. So, this way the warm air goes up. So, the cold high pressure air comes down and fills that place where warmer air left.

So, this happens with the valley breeze and in the mountain breeze what happens in the night is then again denser cool air slides down the slopes to settle in the valley. So, this way the process goes on goes on warm air moves up then cold air comes down and fills that place. So, this process goes on in during the day. So that is called valley breeze in the night it is called mountain breeze. So, this particular figure is taken from Encyclopaedia Britannica.

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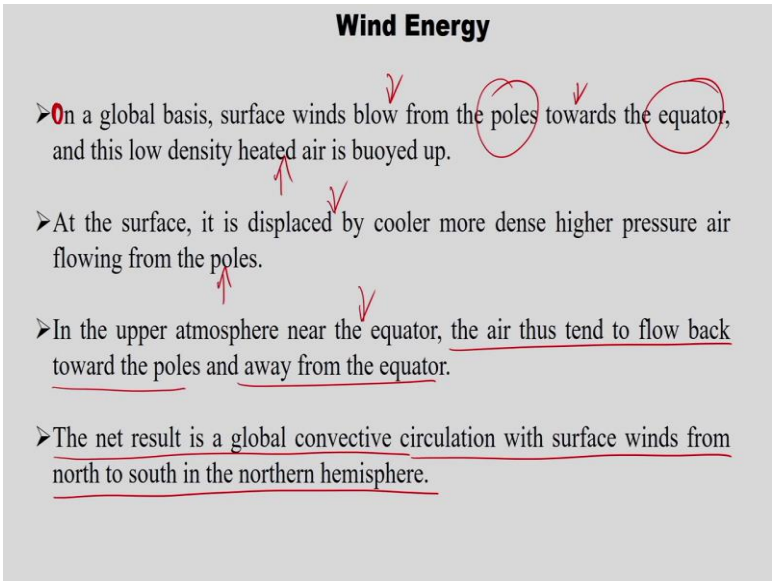

So, on a global basis, surface winds blow from the poles towards the equator and this low-density heated air is buoyed up, it is not only happened locally, so locally, it happens in the land and lakeside and also valley and mountainside and it is not only the local global perspective also wind blows from the poles towards the equator. You are now comfortable with poles and equator those terminologies whatever we have discussed in lecture 1 and this low-density heated air is buoyed up.

At the surface, it is displaced by cooler, more dense high pressure air flowing from the poles. In the atmosphere near the equator, the air thus tend to flow back towards the poles and away from the equator this warm yet goes towards the poles and from the poles cooler high pressure air comes towards the equator, the net result is global convective circulation with the surface winds from north to south in the northern hemisphere. So, wind can be created locally from the land side, lake side and valley and mountain side and in global perspective, it also happens between poles and equator.

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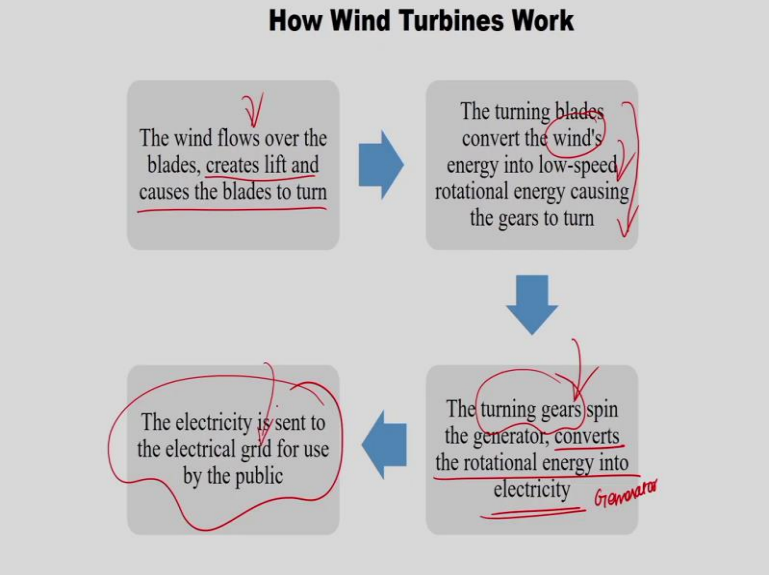

So, this wind energy we can use it for electricity production. So, then how this electricity is produced using this formed wind. So, wind flows over the blades which is in the turbine wind turbine, which creates the lift and cautious the blade to turn. These turning blades convert the winds energy to low speed rotational energy causing the gears to turn. So, wind's energy we are converting into low-speed rotational energy which causes the gears to turn.

Then the turning gears spin the generator, the turning gears convert that low-speed rotational energy into high speed rotational energy and converts further the high speed rotational energy into electricity using a generator. So, there is a component called generators as well. So, then the electricity produced is sent to electrical grids for use by the public. So otherwise, it can be used as a standalone also without grid.

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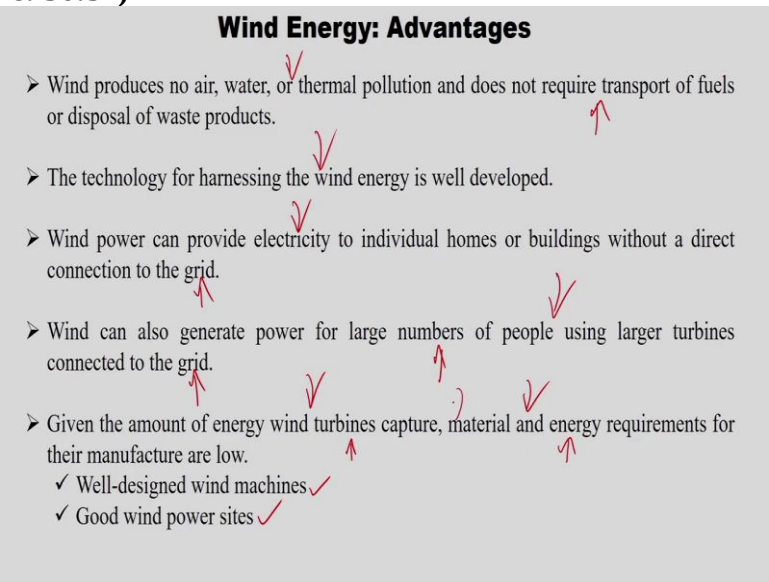

Wind produces no air or water or thermal pollution and does not require any transport of fuels or disposal of waste products. This is the main advantage it is not only with the wind it is with solar also the same thing is true. The technology for harnessing wind energy is well developed now, wind power can provide electricity to individual homes or buildings without direct connection to the grid.

This I already told if the requirement is large it can be connected to large turbines and further connected to grid further electricity usage for the given amount of energy wind turbines capture the material and energy requirements for their manufacturing are low. Because if you have well designed wind machines and good wind power sites then this criterion is made.

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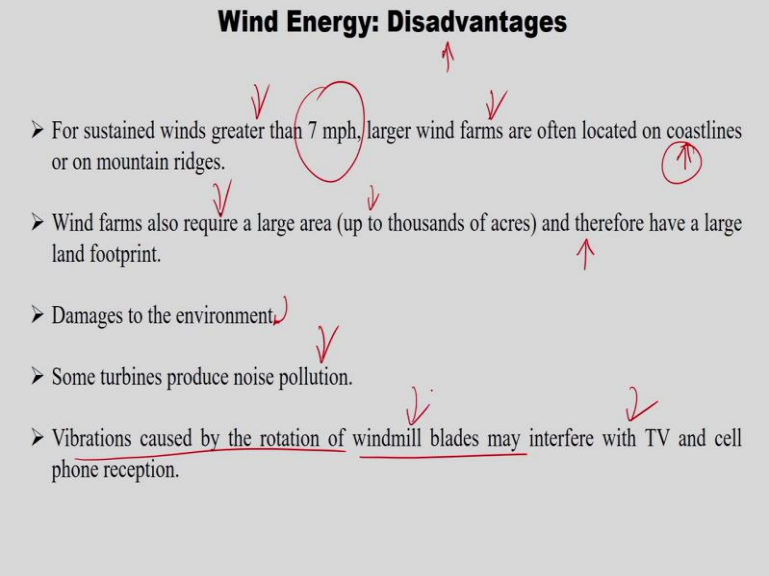

For the disadvantages side for the winds greater than 7 mph, the larger wind farms are often located on coastal line or on mountain ridges. Because we had said that the coastal line and mountain ridges are source of wind formation. So, if you put the wind turbines in the higher heights near the coastal line or mountain ridges, there may be a disturbance for the scenic beauty. So, that is one disadvantage even at home.

So, if you want to use standalone wind energy production, then you need to employ such a tall windmill. So, some may complain there is a aesthetic sense disturbance even at home. So, wind farms also require larger area and therefore have a large land footprint. So, this is another problem and damages to the environment also happens if the birds fly near the windmills or wind turbines, they may get killed because of blades rotation.

So, in that way, there may be a damage to environment it may not be in terms of pollution, but this way there is a imbalance in the environmental aspect. So, some turbines produce noise pollution that is another a disadvantage, the vibrations caused by rotation of windmill blades may interfere with TV and cell phone reception. So that is another disadvantage when using wind energy.

So, here in the wind energy we just discussed about the working principle. So how wind is formed and how the electricity is generated using wind energy and what is the disadvantage and advantages in upcoming lecture for wind energy utilization. There we will discuss in detail about the design of the wind turbines and how it helps harvesting wind and converting them into electricity.

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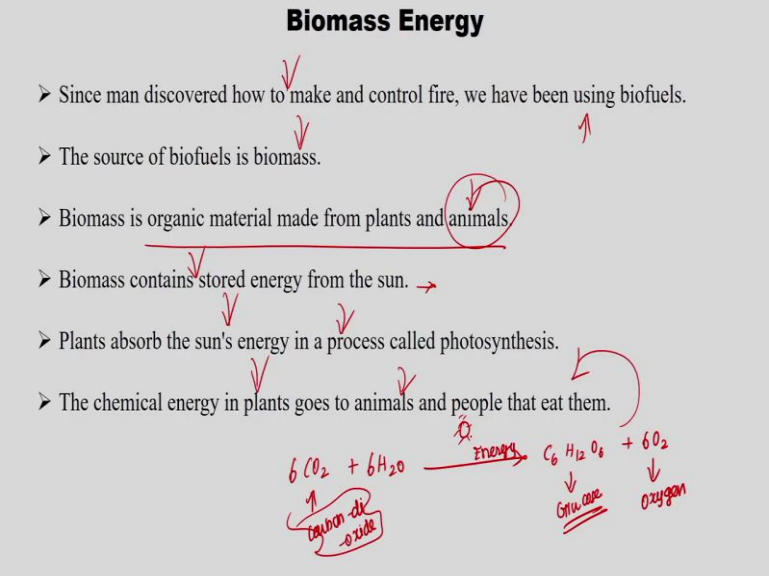

So, the next solar energy utilization indirect method is biomass energy. So, since man discovered how to make and control fire, we have been using this biofuel. The source of biofuels is nothing but biomass. Biomass is nothing but organic material made from plants and animals, but nowadays, we are not using this route. But this is good olden days they used animals as well as a biomass source biomass contains stored energy from the sun.

So, this stored energy when burnt then you can get as a heat. The plants absorb sun's energy in the process called photosynthesis, that chemical energy in plants goes to animals as well as people that eat them. So, the photosynthesis process is nothing but so, they plants take CO 2 and water in presence of sun's energy they produce glucose. So, which is nothing but C 6 H 12 O 6. So, this is 6 6 C 6 H 12 O 6.

Then you they give away oxygen. This is carbon dioxide. So, which is nothing but greenhouse emission gas greenhouse gas or I write carbon dioxide. So, they take and in the presence of water and sun's energy they produce glucose which is nothing better energy. So, when you eat plants then you will get energy you will get this chemical energy in plants which goes to animals and people when they eat. So, but this is the photosynthesis process they produce their energy in presence of sun. So, this process is called photosynthesis.

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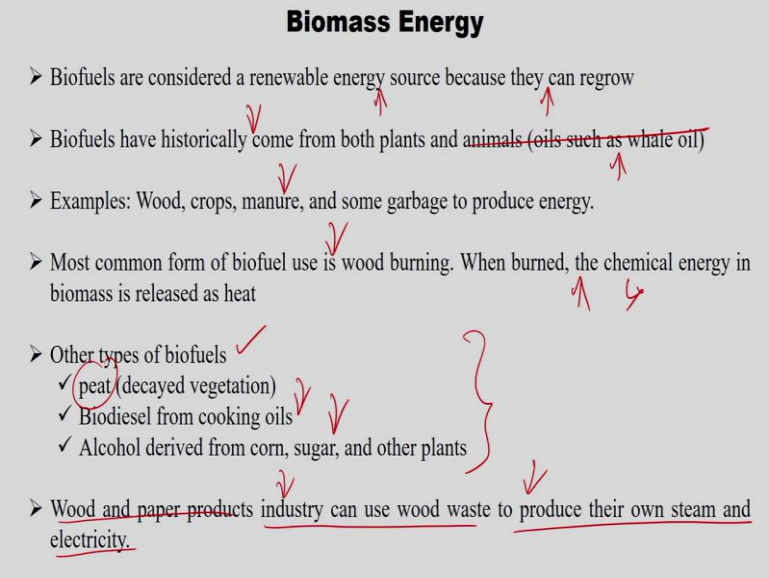

So, biofuels are considered as a renewable energy source because they can grow. So, here we told that we are using this plant material as a bio mass. There may be another aspect we are cutting down the trees. But it is one way it is balanced kind of so, when you are cutting the trees then what is happening you are reducing the oxygen but when you regrow, so, then again it takes the carbon dioxide which is nothing better greenhouse emission gas and again using the sun's energy it produces the photosynthesis effect.

So, in that way, biofuels are considered us renewable energy source because when you are using biomass parallelly you can grow them as well grow plants as well. So, biofuels have historically come from both plants and animals. So, oil such as whale oil was produced from animals, but this route is now completely banned. Examples for bio fuels are woods, crops manures and some garbage to produce energy.

Most common form of biofuel is nothing but wood burning that we are doing. Since the man found out the fire, how to cook food and eat when burned, the chemical energy in bio masses

released as heat this is what we do. So even when you burn the chemical energy is released as heat whatever it is stored inside the biomass, or if you eat them also you would be able to get that chemical energy as a form of energy.

Other type of biofuels are, peat which are nothing but the decayed vegetation and biodiesels from cooking oil and alcohol derived from corn, sugar and other plants. These are also called biofuels, which are derived from biomass. The wood and paper products industry can use wood waste to produce their own steam and electricity if they use the biomass because the wood and paper products industry would get a lot of waste in terms of biomass, they can use that to produce their own steam and electricity requirement. In that way that industrial processes very much sustainable.

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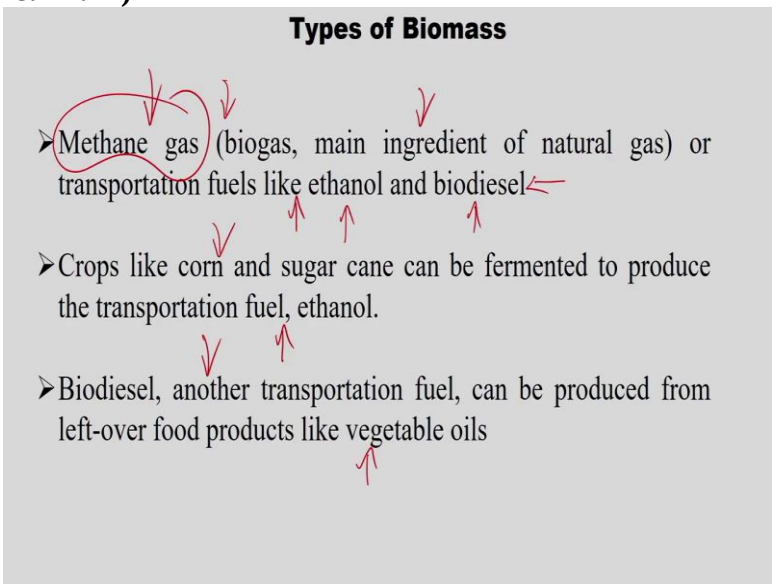

So, there are 3 major types of biomass one is methane gas, methane gas is also greenhouse gas methane gases called as biogas, which is the main ingredient of natural gas or transportation fuels like ethanol and biodiesel. So, these comes under the category of biofuels, either ethanol, which is nothing but a bio ethanol and biodiesel and methane gas. So, all comes under the category of biofuels.

And crops like corn and sugar cane can be fermented to produce transportation fuels, like ethanol, so that also another type of biomass and biodiesel. Another transportation field can be produced from leftover food products like vegetable oils from using vegetable oil, you can produce biodiesel and from the crops like corn and sugar cane. If we ferment them, then we

can produce the bio ethanol. Apart from this we can also get methane gas from municipal solid waste.

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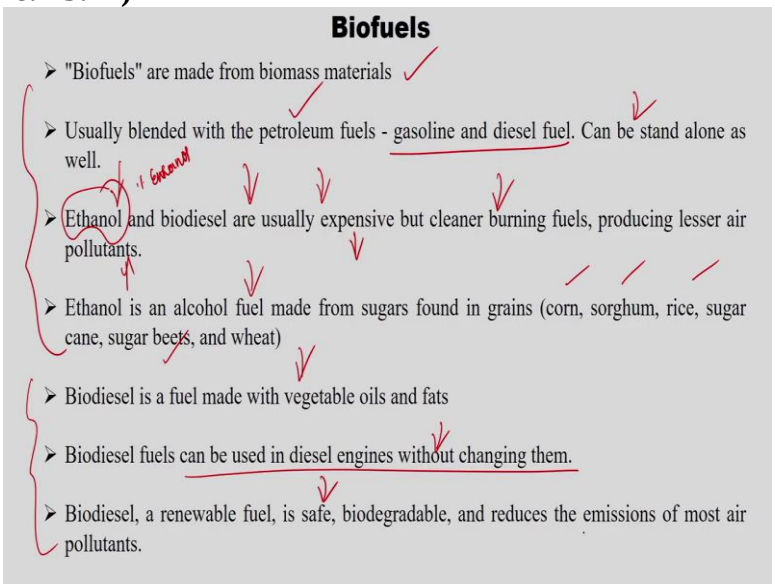

Biofuels are made from biomass materials usually blended with petroleum fuels, gasoline and diesel fuel can be stand alone as well. So, these biofuels can be standalone fuel or mixed with the gasoline or existing diesel fuel it can be used for all purposes. Ethanol and biodiesel are usually expensive, but cleaner burning fuels producing lesser air pollutants, if you compare with normal gasoline or diesel oil, this may be expensive, but they are cleaner burning fuel.

So, research efforts are to reduce them. If you use cheaper sources, then it the cost might get reduced. Ethanol is an alcohol fuel made from sugars found in grains maybe corn, sorghum, rice, sugar, sugar beets, wheat extra. Biodiesel is a fuel made with vegetable oils and fats. So, these are about the ethanol route how the bio ethanol is produced. Then another is biodiesel, biodiesel is a fuel made with vegetable oils and fats and they can be used in diesel engines without changing them we can use directly.

So that is why it is called biodiesel. Even bio ethanol is can be used as a biofuel, but there may be some modifications should be done with the present gasoline engines. Because the amount of the percentage of ethanol you mix with the ethanol, you mix with the gasoline that determines what modifications you would require in the engine biodiesel is a renewable fuel is safe, biodegradable and reduces the emissions of most air pollutants.

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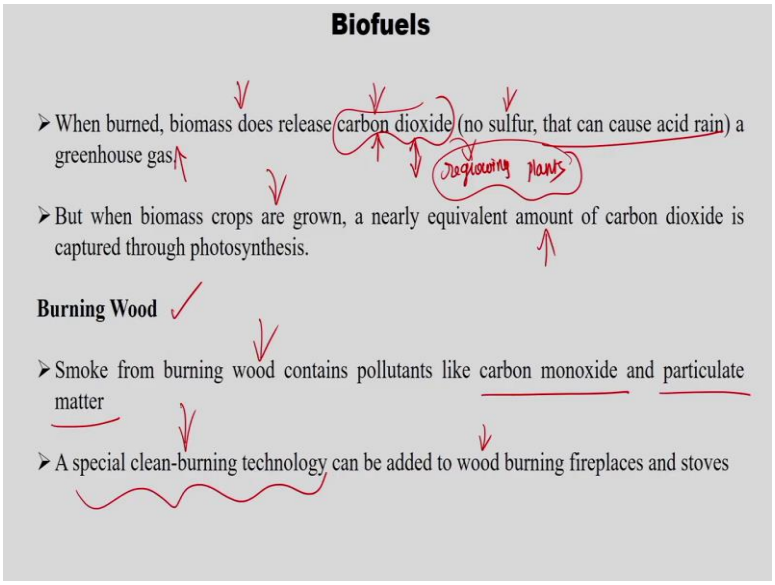

Now, we are going to see what is the environmental effect of certain biofuels when biomass is burned, it releases the carbon dioxide, but it will not release any sulfur components in that way. It is not participating into acid rain, environmental effect, but obviously, when they burn, they release the carbon dioxide which is again the greenhouse gas. So, how we are balancing this emission is by regrowing plants when you burn them you release the carbon dioxide but that will be again reabsorbed by regrowing plants.

So, this is what is the balance. But when biomass crops are grown nearly equal amount of carbon dioxide is captured through the photosynthesis effect. We have already seen by using CO 2 and water and in the presence of sun's energy it converts that glucose which is food for plants and also it releases the oxygen that we are breathing. Burning wood, smoke from burning wood contains pollutants like carbon monoxide and particulate matter.

But if a special clean burning technology is introduced for wood burning fireplaces and stoves, then it can be a good alternative fuel. Because even in certain parts of the country, we are stopping this wood burning, especially in higher pollution days. So, if we have special clean burning technology for burning wood, then we may use it even during worst pollution days.

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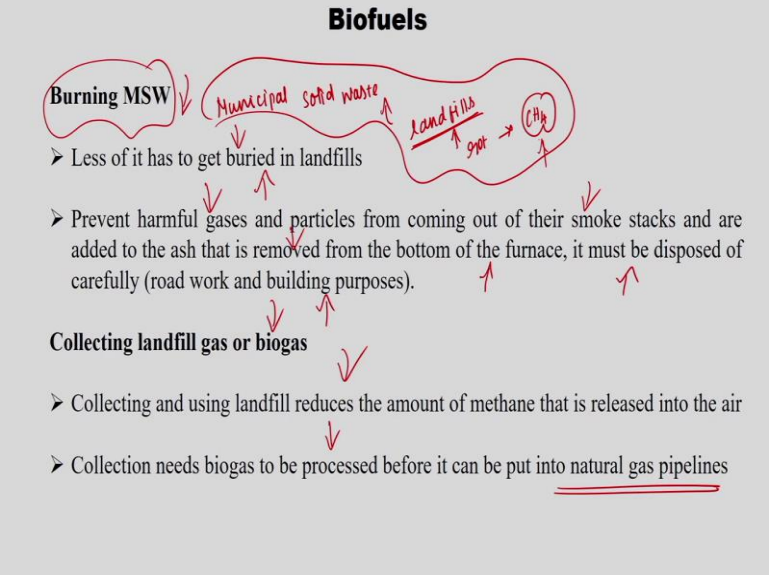

The next one is burning MSW, which is nothing but municipal solid waste. So, the normal technology for handling this municipal solid waste landfills. So, you put it in the underground land. So, that technology is called landfills then after it gets rotten, then you would receive the methane. So, this is again the source for natural gas. This is one particular technology, our lot of it has to be get buried in landfills.

But to prevent harmful gases and particulates from coming out of their smokestacks and are added to ash that is removed from the bottom of the furnace, this is the main technology landfills put all municipal solid waste and produce the methane gas, but instead of doing that one can burn as well. If they are going for this option of burning municipal solid waste, then less would be getting buried in the landfills.

But while burning municipal solid waste you might end up in getting harmful gases and particulates. So, that has to be carefully captured and added to the ash that is removed from the bottom of the furnace which is used to burn the MSW and it must be disposed of carefully or it may be used to for roadwork or building purposes. So, when you are burning municipal solid waste, then you might end up in getting or harming the environment.

The another technologies collecting landfill gas or biogas, which is nothing but meeting collecting and using a landfill reduces the amount of methane that is released into the air. So, if you just to store municipal solid waste in the landfill site might produce CH 4. So, if you are not collecting them back then it will release to atmosphere CH 4 also a greenhouse gas then it might end up increasing the global warming.

But collection needs biogas to be processed before it can be put into natural gas pipelines. As I said that is one of the resources of natural gas without processing without further processing you cannot directly use the methane which is captured using landfill you need to do further processing. So before introducing them into natural gas pipelines, comparing these 2 technologies.

One is you use it in landfill or you use are you burned, when you are putting into landfill you supposed to collect CH 4 back and further process and put it into natural gas pipelines. But if you are burning MSW, then you supposed to collect the harmful gases and particulates and dispose them very carefully based on which would be possible in terms of economical aspects or which would be feasible to apply in the industrial sector based on that they choose the technology whether to burn or put it in landfill and collect the CH which is nothing but CH 4 which is nothing but a biogas.

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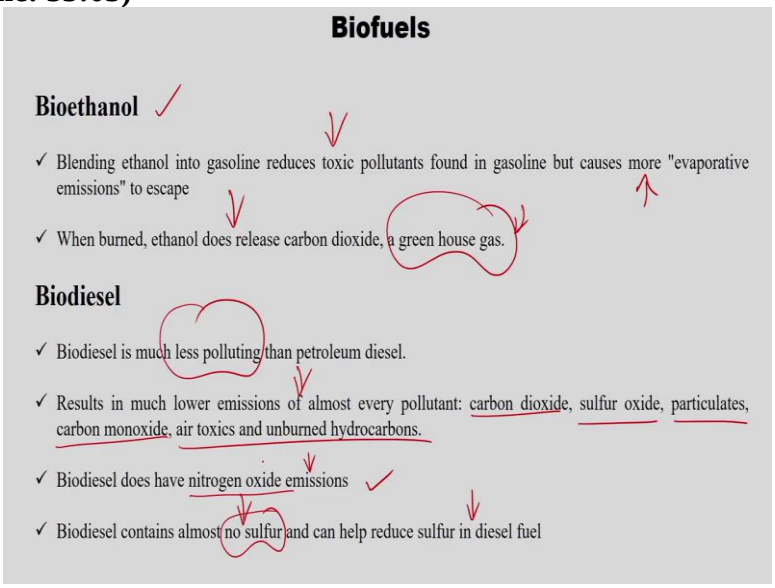

The next one is bio ethanol. blending of ethanol into gasoline reduces the toxic pollutants found in gasoline, but causes more evaporative emissions to escape. So, when burned ethanol does release carbon dioxide again, the greenhouse gas that one needs to be careful. biodiesel is much less polluting than the petroleum diesel results in much lower emissions of almost every pollutant carbon dioxide, sulfur dioxide, particulates, carbon monoxide, air toxics and unburned hydrocarbons compared to normal petroleum diesel fuel.

Biodiesel does have nitrogen oxide emissions, but it contains almost no sulfur and help in reducing sulfur in the diesel fuel. So, it does not have sulfur, but it has nitrogen oxide, but

when you mix with the petroleum fuel instead of standalone, then this effect might get reduced. As I said earlier ethanol when you are directly going for the engine fuel, it is not possible so you need to mix with the existing gasoline and use them and based on the percentage of ethanol you add into the gasoline the engine modification may be required.

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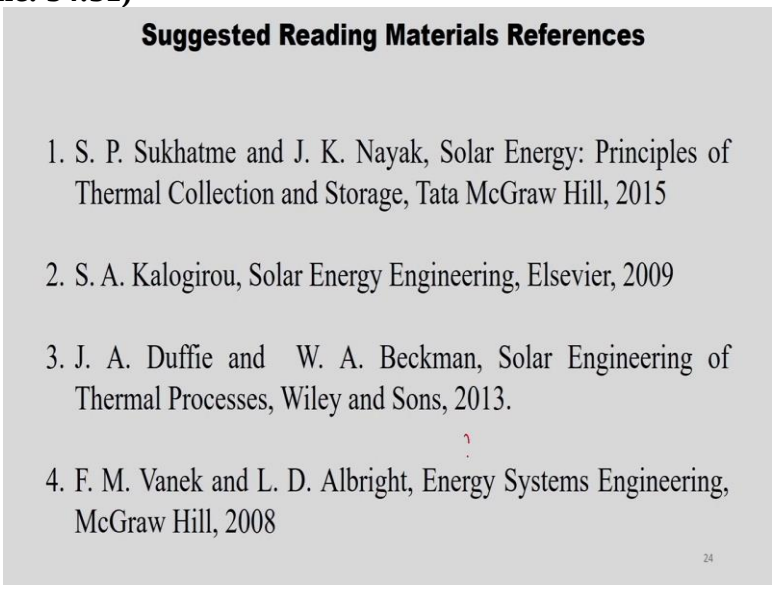

So, that is all about biomass energy, these are all the reference materials for this particular lecture. So, from here the economic aspects of solar collector was discussed using this particular reference. And before concluding this lecture, I would like to discuss a few things whatever we have learned till now, this is the third week of the course, in first week we learnt about the basics of solar radiation, we learnt about Sun, Earth and their relationship and then formation of the atmosphere and what are all the radiation parameters.

We need to learn to harvest the solar energy and you further use them for thermal applications. The second week, we learn about how to collect the solar energy in that non concentrating collectors and concentrating collectors we have discussed in terms of collection of solar energy. In this third week of the course, we discussed about the thermal energy storage technique to use thermal energy in half sunshine hours.

And today we discussed about solar energy utilization method as I mentioned earlier, there are many indirect methods, but here in this particular course, we restricted ourselves to biomass energy and then wind energy. So, here we discussed very basic biomass conversion techniques, which is nothing but biofuels. In subsequent lectures from week 4 onwards, professor gout would continue the biomass conversion.

How the solar energy helps in getting biomass and further biomass energy conversion after him finishing, biomass conversion, then I will continue about the wind energy. So, basically, till now we learn solar thermal conversion. The next 2 subsequent weeks, professor gout would discuss about biomass energy conversion techniques. And then the last 2 weeks lecture will be on wind energy conversion techniques. Thank you.