Sustainability Through Green Manufacturing System: An Applied Approach

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Lecture – 23
Renewable Sources of Energy Continued

So, let us continue our renewable sources of energy session here. So, the next kind of energy we have here is fuel cell. So, what is a fuel cell?

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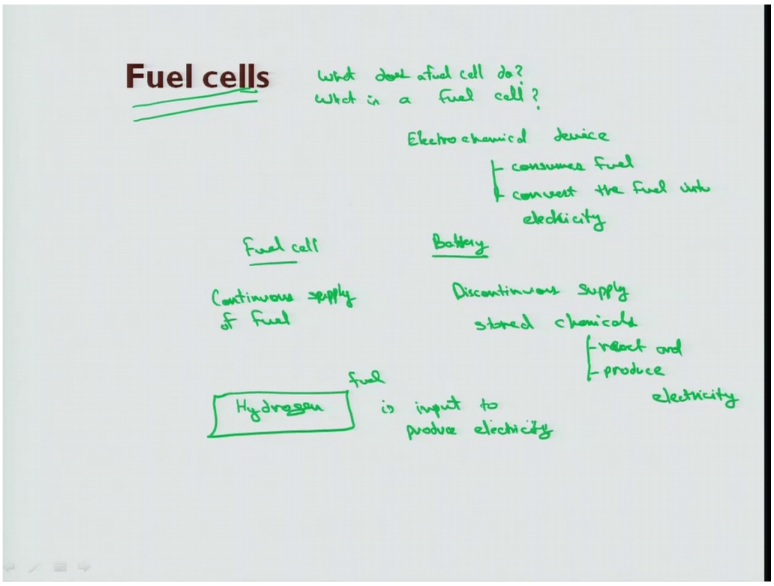

What is a fuel cell? Fuel cell is a electrochemical device. So, what does it do, what does a fuel cell do. So, it consume energy this is electrochemically wise that is fuel cell consumes not energy consumes a fuel and convert this fuel into electricity.

So, this is very much similar to a battery. So, if we compare fuel cell and a battery the working is very much similar, but the major difference is that in which in this fuel cell we have continuous supply of fuel and in battery you have discontinuous supply that is it has chemical stored inside. So, battery has stored chemicals stored chemicals which react and produce electricity.

So, for the stationary fuel cell power systems which are valid for commercial power generation the major fuel that is used here is hydrogen. So, this hydrogen fuels are would say is input to produce electricity. So, electrification different tools may take place in the form of different chemical process is electricity generation.

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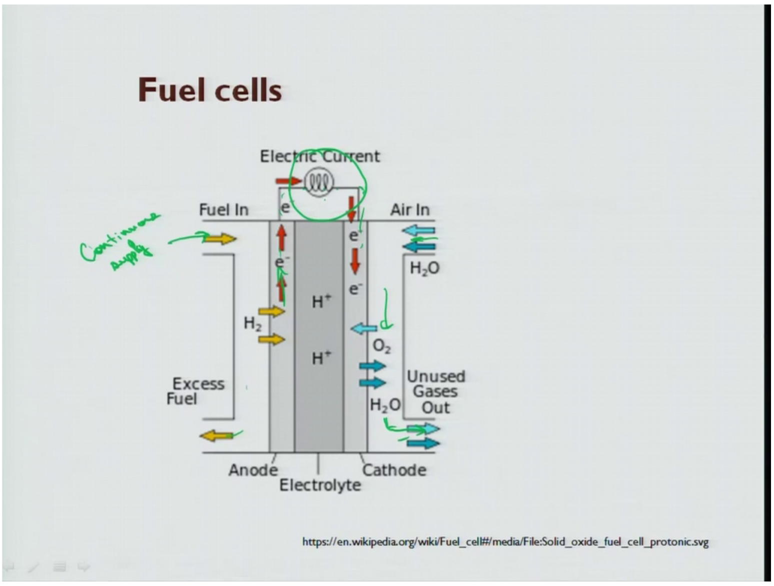

So, a typical fuel cell that is hydrogen fuel cell can be seen here. So, we have hydrogen that is going in here and electrons hydrogen is here we have it is bitted into ions ionization happens here and electrons are going through we have oxygen a going in here water and air is going in here, and un used gases gases go out. So, this flow of electrons here generates electricity. So, we have a node cathode and this electrolyte here.

In this case this continuous supply is here, this is what is these the major property of fuel cell continuous supply the phenomenon is very much similar to battery, but this is a continuous supply.

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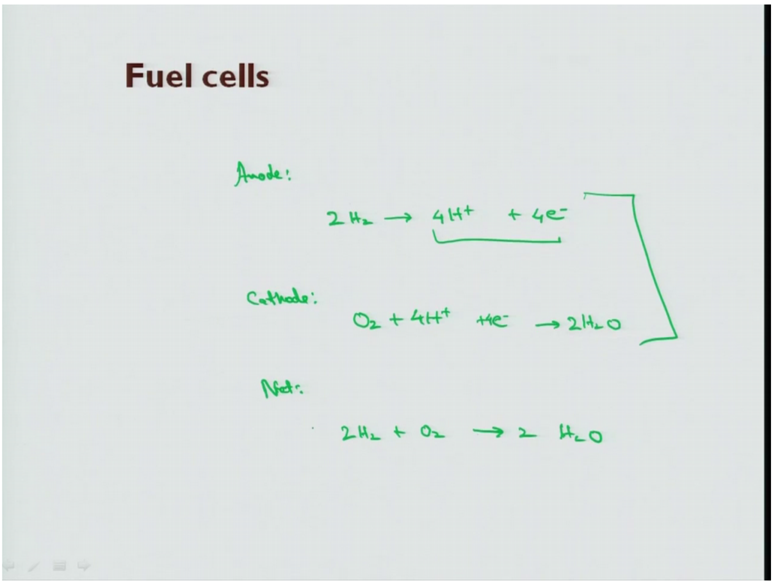

So, the kind of reaction that is happening here is in at anode side the reaction is this hydrogen is being split into hydrogen ions H plus electrons this is 2 into 2 I would balance this direction 4 then 4 electrons then we have cathode. So, at cathode what is happening this oxygen is reacting with our hydrogen ions that is this thing plus electrons to produce water, which is this water is made to go out here.

So, in this case also we have 4 and 4. So, net reaction becomes the hydrogen plus oxygen is producing water this is combining these 2 reactions. So, this is how electrons are being produced here and electricity is generated.

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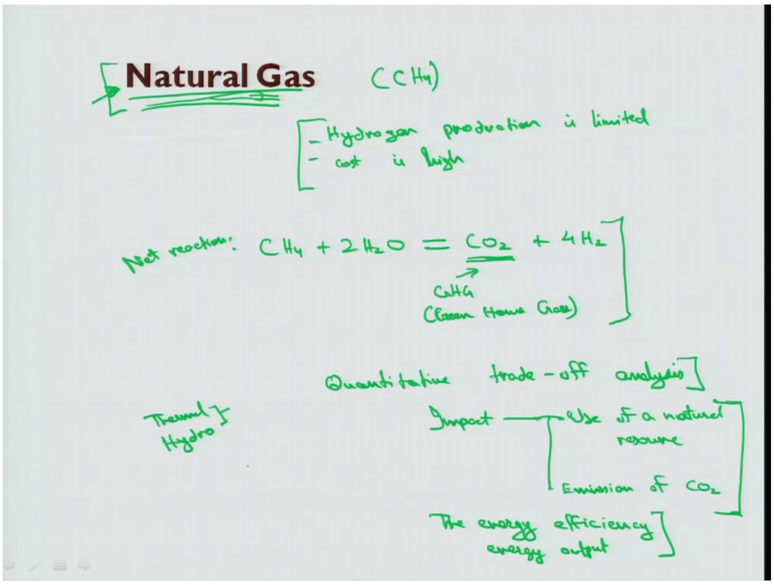

So, another source in place of hydrogen may be natural gas. So, in current stage of fuel cell application there is a limitation of hydrogen production, now hydrogen production has limitations hydrogen production is an issue. So, this is limited.

As well as cost is high in this case. So, stationary fuel cell power systems are available in the market which are primarily built for natural gas fuel. So, natural gas is mainly composed of methane, which is the major component in natural gas. So, in this case the power system leads to generation of carbon dioxide, the reaction becomes CH4 methane plus water generates carbon dioxide plus H2. So, this is directly I am putting the net reaction here.

So, we can see that we have carbon dioxide as an output here. So, a tradeoff has to be made that we are using a kind of renewable energy or may kind of fuel cell which is a renewable energy, but this resources these resources are being used here and carbon dioxide which is a green house gas let say green house gases is produced. So, if natural gas based fuel cell power system is to be used for energy supply for a manufacturing system or for a big and concerned, a quantitative tradeoff analysis must be conductive.

I would better here write quantitative; quantitative trade off analysis that is the impact on both the sides, that is a use of impact use of a natural resource then emissions of carbon dioxide that is carbon foot print these must be evaluated guest the energy efficiency that is the energy output only. So, net environmental vision savings of using the fuel cell power system over local grid electricity that is the local grid electricity might be thermal power plant, thermal if hydro power plant is there then it is good.

So, it has to be compared with this one. So, in such case the life cycle emissions of the fuel cell power system must be considered in this trade of analysis. So, this must be considered to access the affect of environmental mission mitigations.

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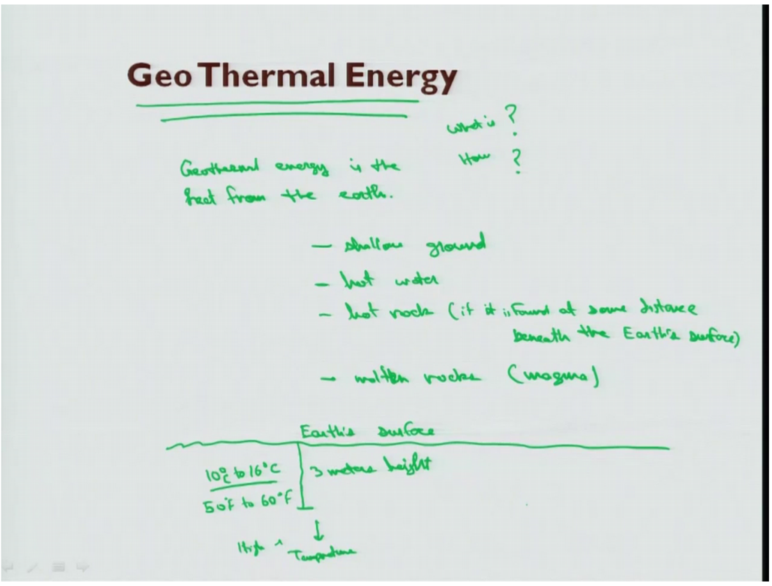

So, next kind of energy I have is Geo thermal energy. So, what is geo thermal energy how do we utilize this one are the question what is and how. So, geo thermal energy is the heat from the earth.

Geo thermal energy is the heat from the earth. So, it is also a clean and sustainable kind of energy, that is sources of geo thermal energy ranges from the shallow ground, hot water then may be hot rock if it is found at some distance beneath the earth, if it is found at some distance and this distance is beneath the ground surface or I would write earth surface. So, these can be the sources of geo thermal energy here.

So, this difference in temperature is utilized to generate electricity. So, even down deeper to stimuli high temperatures of molten rock for example, I would even write molten rocks or magma these can also be utilized. So, almost everywhere the shallow ground or the upper three meters of earth surface three meters is about 10 feets maintains a nearly a constant temperature. For example, if I say this is my earth surface and this is 3 meters height then this temperature here is about 10 to 10 degree to 16 degree centigrades which is equivalent to 50 to 60 degree Fahrenheits.

So, this temperature is always there. So, most power plants needs steam to generate electricity, the stream rotates sector wind that activates a generator which produce electricity many power plant still use partial fuels to boil water for stream. So, geo thermal power plants what they do? They use steam produced from reservoirs of hot water that do there found couples of miles and more below the earth surface. So, when we go below the temperature is higher at certain places.

So, this difference this hot water found at a few kilometer below the earth surface is used to produce steam. So, there are three kinds of power plant, where that use geo thermal energy.

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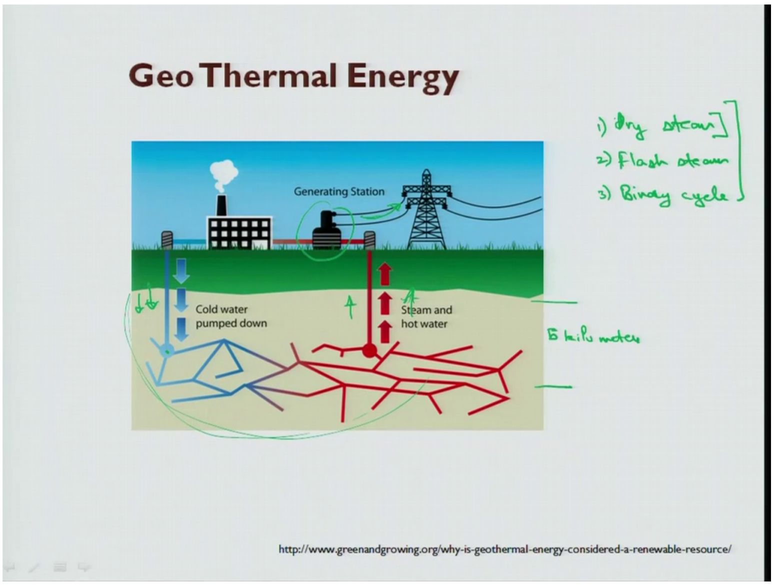

So, this kind of power plant the cold water is pumped down and steam and hot water is coming up. So, this difference is used to generate electricity here, electricity even transported to the grid. So, the transportation is happening here.

So, this is being the cycle is being running. So, this cycle is running continuously here. So, the main issue here is building this set up to take our connection to this much depth. So, this is I say if it is may be 5 kilometers. So, there are 3 kinds of geo thermal power plants, number 1 dry steam geo thermal power plant, number 2 flash steam geo thermal power plant number 3 is binary cycle.

Now, dry steam power plants draw from the underground resources of steam, the steam is piped directly from underground wells to the power plant, where it is directed into a turbine and generator unit.

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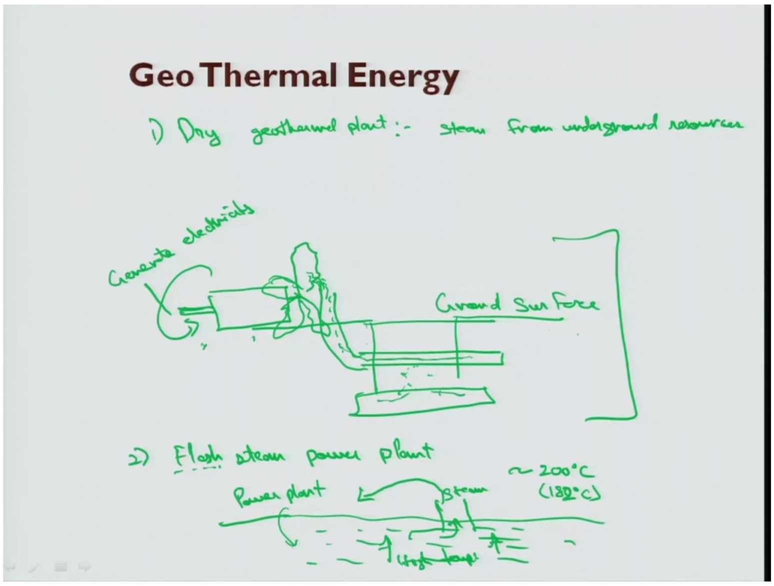

So, this dry flash and binary cycle geo thermal plants have different kind of mechanisms of use number 1 dry geo thermal plant. So, the dry steam of geo thermal plants draw steam from the underground resources.

The steam is actually directly made to pass through the pipes for underground wells. So, we have underground wells here. So, these are well this is ground surface here we steam is made to pass through pipes under where we have pipes going through here and steam is made to pass through here. So, this steam is made to pass through these underground wells to the power plant, where it is directed to turbine.

So, we have the power plant here and the generator or turbine is here with its spins and this steam is made to fall to this turbine and this one turbine is rotating this shaft and we have generated electricity. So, as this steam flows upward the pressure decreases and some of the hot water boils into steam, the steam is then separated from the water and used to power the turbine generator now left over water here condensed.

Now, next I have here is my flash steam power plants. These are similar phenomenon, but it used because see the name here is flash. So, it uses steam that is there in water. So, they use geo thermal reservoirs of water with temperatures may be of the order of 200 degree centigrades. So, this hot water flows upward under its own pressure and when it is flows upward the pressure decreases some of this water boils into steam.

So, this water we have water here the water reservoirs, at some places we have high temperatures here. So, this high temperature made the water to flow up in form of steam. So, this steam is captured here, we have steam here this steam is captured here and it is made to flow to our power plant. So, this is again we have the similar kind of arrangement here turbine is being run by this steam and steam is electricity is generated. So, anyway water or condensed steam here are injected back into the reservoir here. So, anyway water is injected back.

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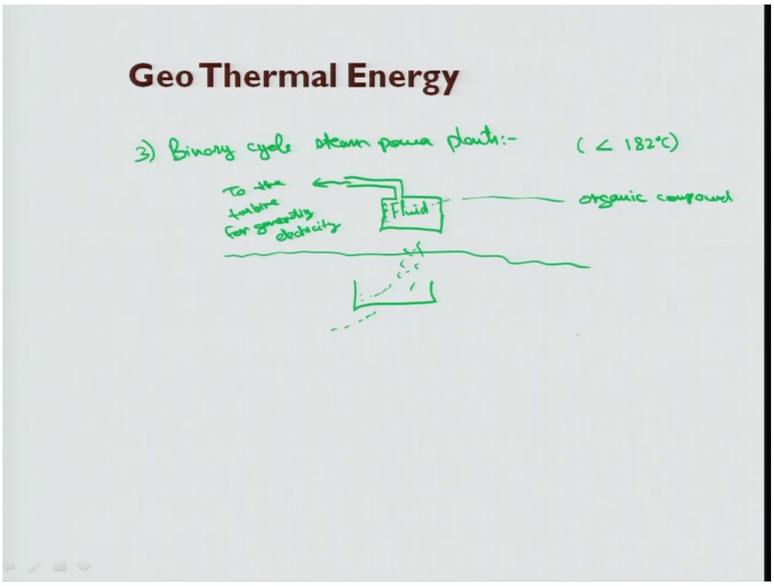

So, another is third one binary cycle; now these a pattern water at low temperatures. So, they have the temperature these less that is of the other temperature was this was of the of the order of the 200 degree centigrade if it is specifically in us they say it 182 centigrades. So, in this case temperature is less than 182 degrees.

So, these plants use the heat from hot water to boil a working fluid and which usually an organic compound with low boiling point. So, this working fluid that is an organic compound is then vaporized in a heat exchanger to turn a turbine. So, the water is an injected back to the ground that is reheated. So, these cycles is made to run again and again. So, there are no air emissions or very little air emissions in this case.

So, this is similar to this process flash, but the difference is that in place of taking this steam directly to the reservoir, this steam is used to heat a fluid here used to heat a fluid here this fluid is this is an organic compound generally. Now this fluid is heated and is then made to the turbine to generate an electricity for generating electricity. So, this is only difference from the flash steam process.

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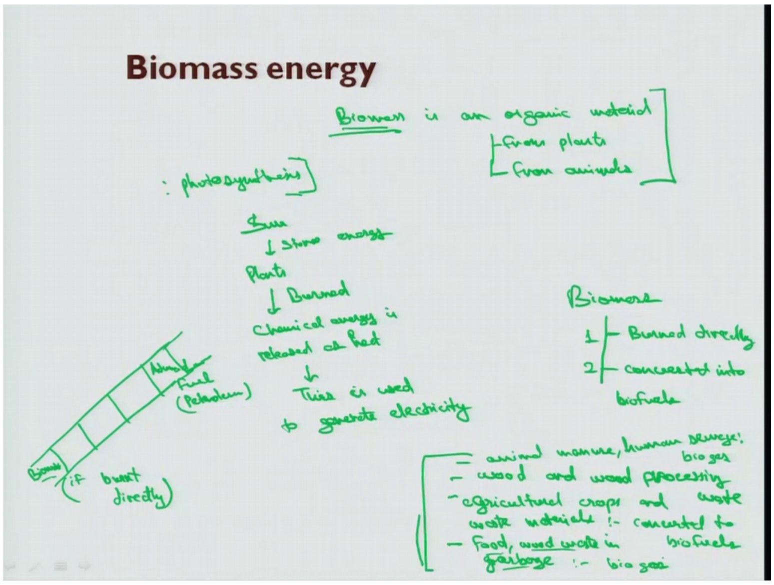

So, next I have is bio mass energy. So, what is biomass? Bio mass is an organic material bio mass is an organic material that comes from plants and animals plants and from animals. So, you might have heard of the term photosynthesis what is photosynthesis? Plants absorb the energy of sun and this process is called photosynthesis, this energy of sun is again then turned into the bio mass which is used as then renewable source of energy here this bio mass.

So, when bio mass is burned this chemical energy, energy in bio mass is released as heat. So, this photo synthesis actually this is sun that stores energy in plants. So, when this is burned, chemical energy is released is released as heat which can be used. So, this is used to generate electricity. So, this bio mass can be either burned directly, but this creates smoke or it can be converted into bio fuels.

If you could recall we had an energy ladder in which we had the bio mass here and here we had the advanced fuels that is petroleum etcetera. So, this was actually if we burn this directly, if here this was the condition if burnt directly. So, some examples of bio mass and their uses of energy are wood and wood processing waste I can even write it here wood and wood processing waste then these are burned to heat buildings to process heat in industry and to generate electricity.

Then we have agricultural crops and waste materials then these are burned as fueled or they are converted to liquid bio fuels, then along with this we have food or wood waste in garbage also we have animal manure. So, this animal manure are may be human sewage. So, these are also converted into bio gas which can be burned as a fuel. So, in this case food wood waste, garbage these are also burned to generate electricity in power plants or they are also converted in to bio mass bio gas here.

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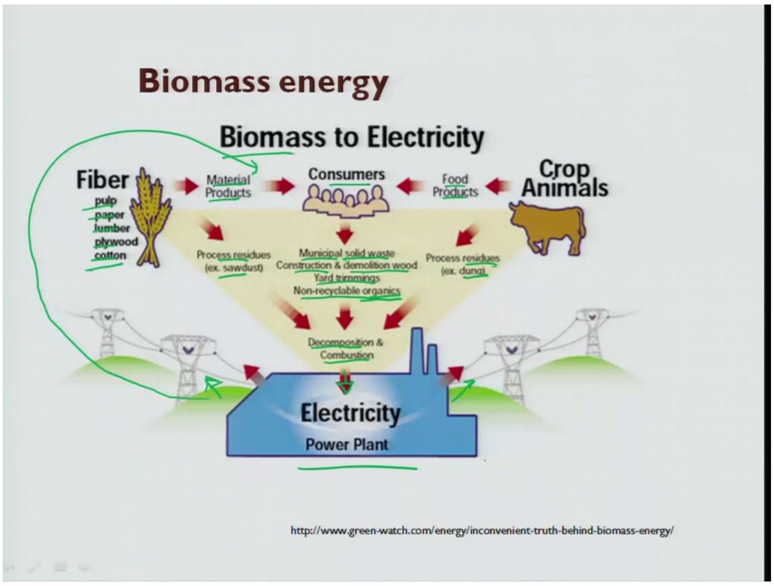

So, I have a kind of electricity generation plant in which we have this bio mass materials as input. So, in this case this electricity is produced and being supplied to the grids here, the bio mass here is the pulp paper plywood cotton anything can be used and from animal sides also we have animal residues say dung etc. So, here also we have process residuals. So, this fiber can be used to make materials then consumers used at then food products also the consumers could used here and when the consumer use the waste is produced, waste that is bio you can be uses as bio mass the solid waste.

The municipal corporation can segregate the waste into the categories the waste that can be used as bio mass that is from construction demolition wood, yard trimmings, non recyclable organic compounds here they can be used. So, this decomposition and combustion can be done to have electricity, which can be again used by the consumers here this is a kind of a bio mass cycle here bio mass can be used in this way.

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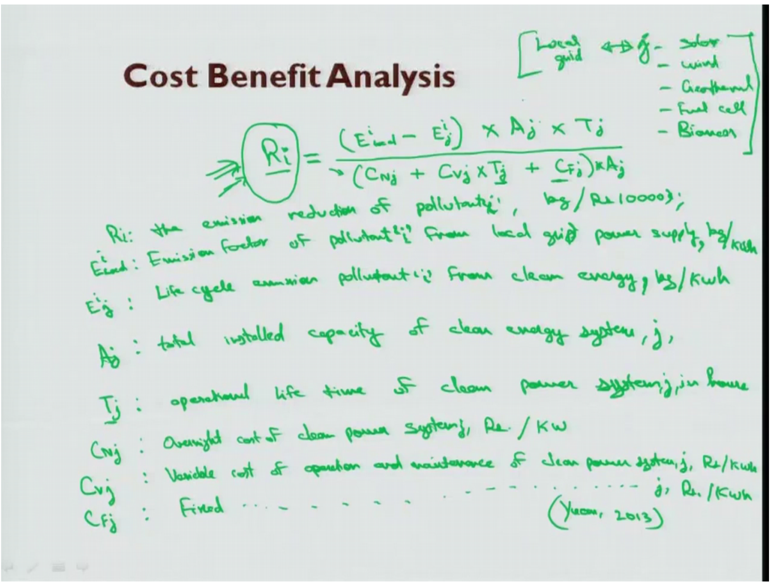

So, next as I have discussed certain kinds of renewable sources of energy, it is cost benefit analysis. So, to conduct the cost benefit analysis various models are available to know the pollution reduction to have the tradeoff between the cost and benefit and to have the relation between the various efficiency levels and for all kinds of energy here.

So, one of the model here is developed by Yaum in 2013 which can be applied to all kinds of clean energy, in this model we have R i. This model takes into consideration the emission factor this is actually vr we have emission factor that is of pollutant from local grid power supply. Another factor it takes into a count is the life cycle emission of what of the pollutant.

If I say one pollutant pollutant i this pollutant i may be carbon dioxide this may be the some other air emissions. So, if I say pollutant i here this may be carbon dioxide sulphur phosphorus or other pollutant emissions. So, in certain cases if I say life cycle emission of pollutant this same i from the clean energy right. So, in this case for example, in certain clean energy cases this pollutant might even be 0. So, here we have the difference of these 2 factors if I say this factor is E for i pollutant emission for i pollutant from local grid and this is emission of i pollutant from my clean energy here j is my clean energy.

So, this is kilograms of carbon dioxide that is produced per kilowatt hour, if I say carbon dioxide is the pollutant that is chosen here or this is again kilogram of the pollutant per kilowatt hour these are the units here. So, this difference E i local minus E i of my clean technology is a factor here. So, this factor also involves total installed capacity of clean energy. Now this total installed capacity is again multiplied here I will put it A j installed capacity Aj clean energy system here, the system j.

Now, I have Tj here as well, Tj here is operational lifetime of clean power system here the operational lifetime I can put some unit may be in hours in minutes whatever like. So, this is also a multiplicative factor here. So, this R i is proportional to that is what is R i that is also needed to define here R i is the emission reduction of pollutant that may be this pollutant i which the units may be kilograms per rupees one lakh may be these are the units.

And also this emission reduction factor is inversely proportional to our cost. So, here I have the cost over I would say overnight cost of clean power system. So, this cost is rupees per kilowatt. This is overnight cost of my clean power system j is my clean power system and plus I have variable cost of operation and maintenance of my clean power system this is clean power system j this is clean power system.

This is also the time is for my clean power system j, this cost is Rs per kilo watt hour. So, this is variable cost of my clean power system j. So, this variable cost of my clean power system j also comes here. So, because this is variable cost this highest dependent on time. So, the time for which my equipment is operating also comes into play here. So, I also have the fixed cost of operation and maintenance of my system j. So, this c fixed cost of my this is fixed cost of operation and maintenance of this clean power system j this is again rupees per kilo watt hour.

So, this cost also needs to have this factor Aj. So, this is my emission reduction of the pollutant this j. J can be my solar wind geo thermal fuel cell biomass any kind of clean energy may be chosen and how is this related to my local grid. This is explained or this is considered here in the present model. So, this cost benefit analysis can be applied on any emission reduction from the grid electricity conversion manufacturing using clean energy supplies.

So, this quantitative result R i is the amount of emission reduction per unit scale of economic unit input or investment. So, we can we can see economic input or investment is on the denominator side. So, per unit economic input or the investment is also there fixed cost is also there. So, it must be noted here that the results are the site dependent on the geographical locations, due to difference of emission factors of local grid power supply and the actual powers output of the clean systems.

So, it is dependent on site here. So, in this section the application of clean energy supply for conventional manufacturing systems are demonstrated, the reductions are taken into account and we have discussed various kinds of clean energy resources and how do we even evaluate their efficiency.

So, I would like to have a break here and in the session that would be a continuation of this session only, will discuss the renewable energy status in India also we will discuss the concept of industrial symbiosis. So, let us meet in the next lecture.

Thank you.