Waste to energy conversion
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Lecture – 23
Energy Production from Waste Plastics – 2

Hi friends. Now we will discuss on the second part of the module Energy Production from Waste Plastics. In the first part of this module, we have discussed on different types of plastics their monomers they are recycling processes and pyrolysis of plastics.

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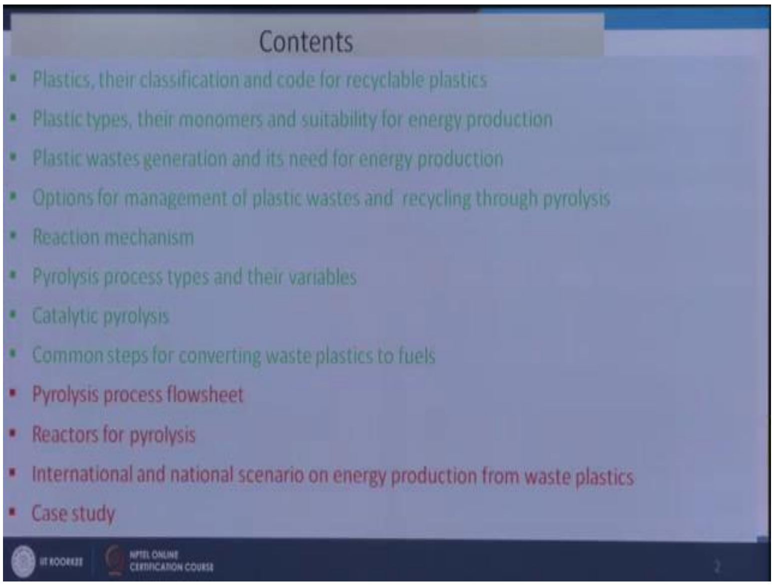

And in this module we will discuss on pyrolysis process flow sheet reactors for paralysis international national scenario on energy production from waste plastics and some case study. So, at first we will see the process flow sheet for the pyrolysis of waste plastic. So, here we see the feedstock is collected from municipal solid waste and then it is cleaned dried and size reduction takes place there is one sort of heat treatment which we have discussed in previous module that is pyrolysis of biomass and waste.

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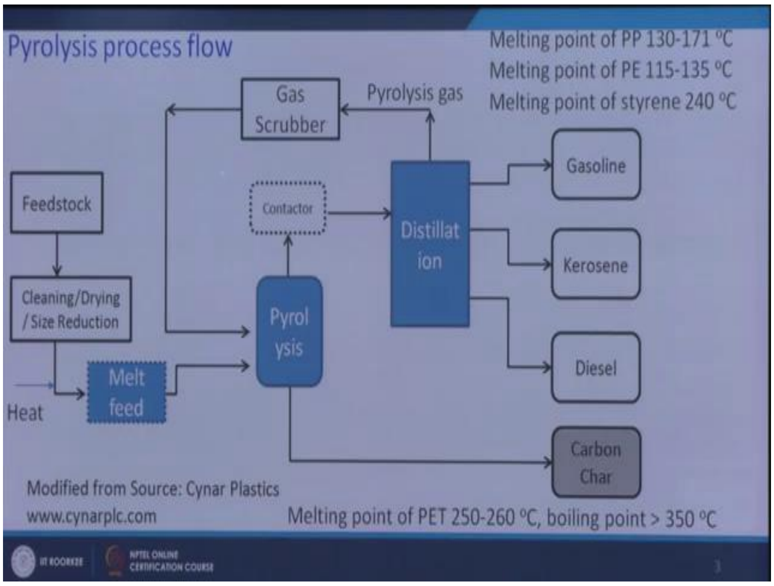

So, similar process is their there is pretreatment and then it is going for heat treatment and melt feed is produced and that melt feed is passed through pyrolysis process or reactor and then pyrolysis reactor the output is coming to contractor. So, from contractor we are getting the separation of different products here say gasoline kerosene diesel from this part and from the bottom of this pyrolysis reactor we will get the carbon or char. So, true the distillation we will get some pyrolysis gas that is used for the production of heat in pyrolysis reactor, but before that it is cleaned.

So, it is passed through the gas scrubber. So, this is the flow sheet for the pyrolysis of waste plastics now if we compare with the flow sheets which we had discussed in the previous module on the pyrolysis of biomass and waste. So, in this in that case this was not there in this case as the feed stocks are very defined and defined and they are having say melting point for PP is 130 to 171 degree centigrade, for P 115 to 135 and for styrene 40 degree centigrade which are mostly used for the production of liquid fuel.

So, during pretreatment step up to heating of say 250 degree centigrade the waste plastic can be meld down and so liquid feed along with some gasses feed can be passed through pyrolysis reactors and so pyrolysis reactors the gas which will produced that can be further used in a contactor to get more contact with say catalyst for particular applications for some example if you want to get more say gasoline page then it will be requiring some additional reactions here. So, some catalyst has to be added that will produce some aromatic ring and the gasoline will be the more product. So, we are having options here either melting or pyrolysis reactor same unit and then this is pyrolysis and conductor same unit.

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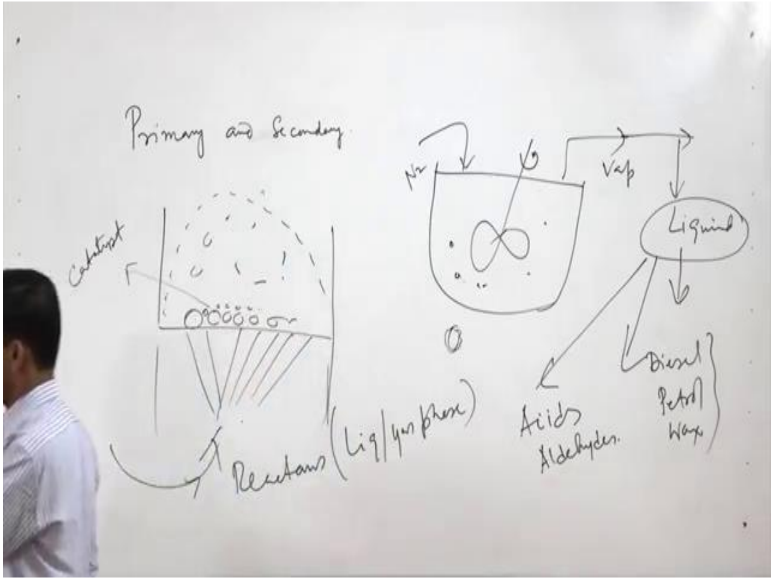

So, primary and secondary pyrolysis units people have used. So, primary and secondary pyrolysis units; secondary units have been used primary this one; either this one; primary secondary or primary and then secondary.

Now, we will see the different types of reactors see if this is the flow sheet then our main factors or main performance will depend upon this portion. So, we will be concentrating here regarding different type of reactors which are used for the pyrolysis of waste plastics.

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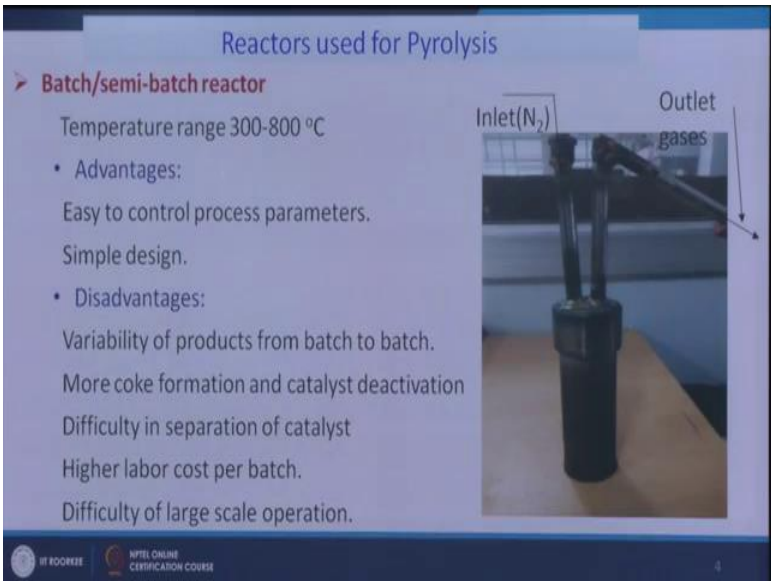

So, first we will discuss on batch type of reactor. So, as soon here this is a batch reactor very lab scale very small scale reactor. So, we here will be putting some material solid plastics if catalyst can also be added then we will heat it. So, pyrolysis will take place and vapor will be going out. So, this route and after condensing here we will be getting the liquid product and nitrogen will be sent to carry the vapors through this.

Similar to the biomass pyrolysis, but here we can add some starting in this reactor because when will be putting heat here. So, at first it will be in molten form. So, if catalyst particles are there. So, some starring will give more mixing. So, one way you will be putting some into an another will be getting the vapor further condensation will give us liquid all will get the fractionation, if you compact the difference or if you compact the properties of this liquid which is produced through the pyrolysis of waste plastics and the pyrolysis of biomass and other organic waste then we will see here this will be say diesel petrol it say it works.

So, these are the compound here, but in other case for other biomass we will not get this things will be getting different types of acids aldehydes etcetera. So, this is the best process we can apply for the pyrolysis of waste plastics, but this process is has some disadvantage that is variability of products from batch to batch one batch to other batch the product will be different more coke formation and catalyst deactivations in this case if you some catalyst and it takes more time it is not a continuous process. So, more carbon will be deposited on the surface of the catalyst and it will be deactivated.

So, this is the drawback of this and higher labor cost for batch and difficulty of large scale operations the volume is less. So, we cannot expect very high throughput through this type of reactor, but what is the advantage of this the easy to control process parameters and design is very simple the venting range here say 300 to 800 degree centigrade in this reactor.

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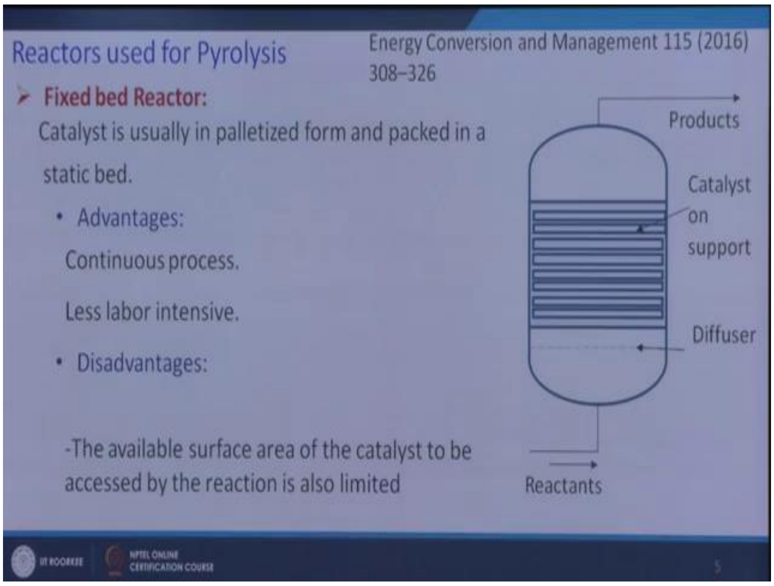

So, next we will see other type of reactors there is say fixed bed reactor. So, fixed bed reactor as shown here in this slide this is related to secondary pyrolysis. So, reactance from the primary pyrolysis is sent through the secondary pyrolysis unit where the catalysts are kept on the some support. So, these catalysts are basically in pellets from in pellets from and those are stored on some support. So, when from the bottom we send the reactance in liquid or gas phase there is outlet of the primary pyrolysis unit. So, those products for reactance will come in contact with the catalyst particles and the composition will change composition change due to catalytic pyrolysis and there are basically 2 types of reactions one is cracking reforming etcetera some aromatization may take place if you take different types of catalyst also.

So, this is the concept of the use of fixed bed pyrolysis reactor for the pyrolysis of waste plastics these reactor system has some advantage and some disadvantage also. So, advantage is that it is a continuous process less labor cost and disadvantage the available surface area of the catalyst to be accessed by the reactions is less because the catalyst are not distributed it is in a on a stored in a fixed bed it is kept on a fixed bed. So, that is why the gases or liquids which is going through this bed those we will get less chance to be in contact with the catalyst. So, this is the features of the fixed which type of reactor then we will discuss on the fluidized bed reactor.

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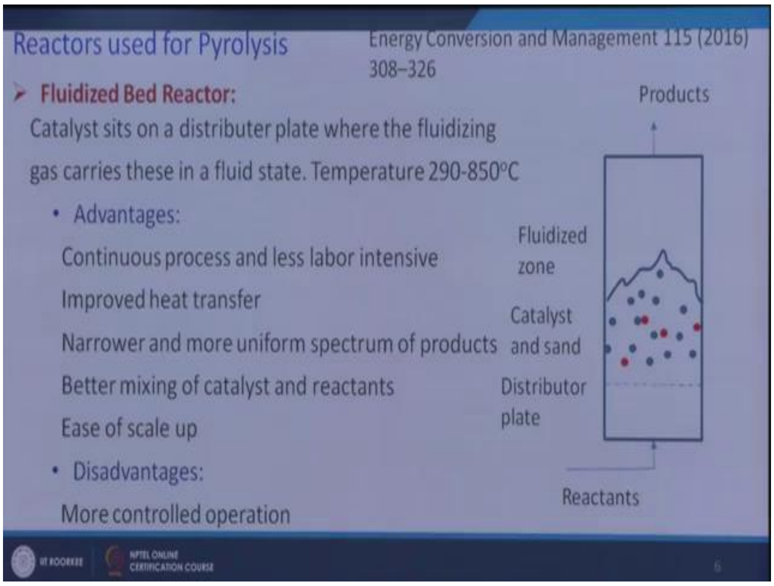

So, fluidized bed reactor gives normally better performance than that of fixed bed reactor and in this case the reactance from the primary pyrolysis unit is send through this bed where the catalyst are kept on some distributed plate. So, catalysts are kept on some distribution plate. So, where these are distributed in to different channels means different parts. So, it is distributed. So now, catalysts are here and in this case some sand particles are sometimes used. So, sands one way it acts as catalyst, other way it helps to transfer heat. So, both ways it helps. So, when we give higher velocity of this reactance. So, those particles will be fluidized in this page there will be fluidized as soon here these are the fluidized particles. So, liquid and vapor to which are coming into this unit that will be getting more chance to be in contact with these particles catalyst particles.

So, more reactions we will get and as discussed in the first part of this module that due to the presence of heterogeneous catalyst that and their active sides particularly the acid sides; acidic sides. So, helps the (Refer Time: 10:41) transfer intermolecular and intermolecular and also the catalyst follows different type of reaction mechanism. So, due to this reason we get narrower and more uniform separate spectrum of products and better mixing of catalyst and reactance and improved heat transfer. So, these are the main characteristics of this process which are favorable for the process some disadvantages that it requires more control because what will be velocity how.

So, that this catalyst will not be carried over all those calculations are required and has to be maintained in a vapor way.

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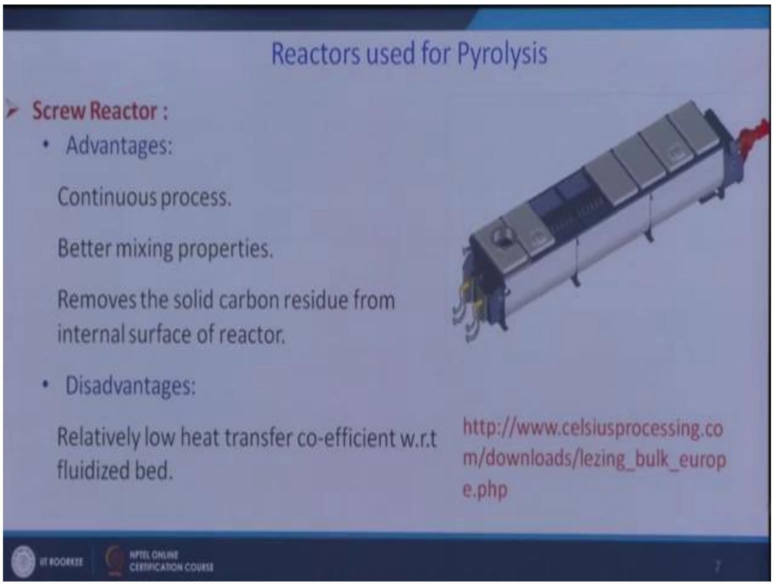

Here also the temperature is 290 to 850 degree centigrade in this reactor fluidized bed reactor. Next will say the screw reactor; so screw reactor already we have discussed in the pyrolysis of biomass and other waste. So, in screw reactor, one screw has shown here say inside this is this is the screw. So, it will be rotating. So, from one side to other side the material will flow. So, when the material is flowing and it is heated from the outside of this. So, there will be some pyrolysis reaction. So, solid heat can be passed through it. So, it will be first melt and then it will go through the pyrolysis reactions and product and vapor and liquid will goes up from it for secondary unit if there is any secondary unit otherwise this will be working as a whole unit of the production of pyrolysis product.

These as some advantage there is this is continuous process it is better mixing properties it gives removes the solid carbon residue from the in internal surface of the reactor so carbon will be deposited in the surface and screw blades will be removing the carbons from these. So, this is the advantage of this process and disadvantage is there is relatively low heat transfer coefficient with respect fluidized with reactor.

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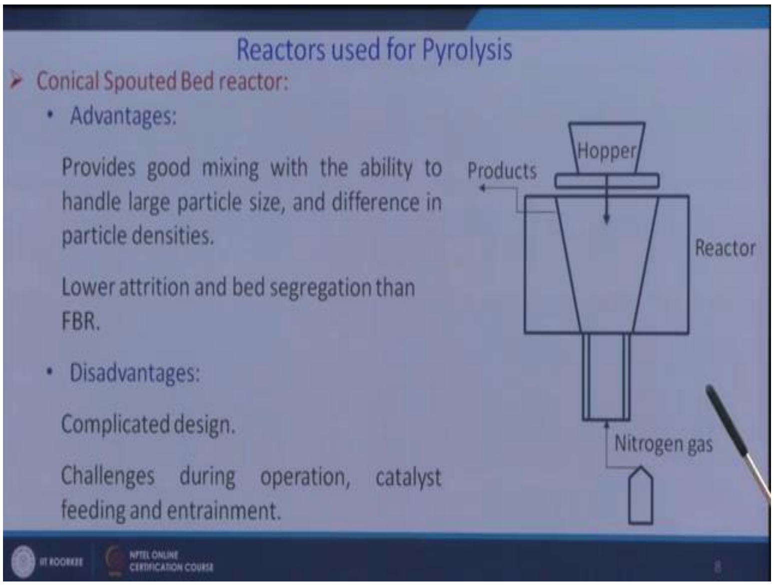

So, next will see another type of reactors which have been reported in literature that is conical spouted with reactor. So, here from the top will put the feed stocks and then from the bottom nitrogen gas and there will be pyrolysis reactions. So, during the pyrolysis reactions will get the vapor.

So, vapor and gas will goes off. So, this is the mechanism just like say conical say reactors we have discussed in previous module for the pyrolysis of biomass and other ways to also. So, similar type of mechanism here, but it has some advantage and disadvantage advantage is the heat that it provides good mixing with the ability to products handle large particle size and difference in particle densities. So, it can handle any type of particles which are having different densities that is in case of using say mixed plastics. So, that will be suitable for this and lower attritions and bed segregations then we are and disadvantage is that it is this design is suitably complicated how to maintain this product flow here.

So, we have putting nitrogen solid material here it is going out. So, challenges during operation catalyst feeding and entrainment. So, these are the features of this and disadvantage and advantage of this type of reactor now we will say some international scenario now what is the status on the production of liquid fuels through the pyrolysis of waste plastics different countries are trying to do it and I will bring some in information here.

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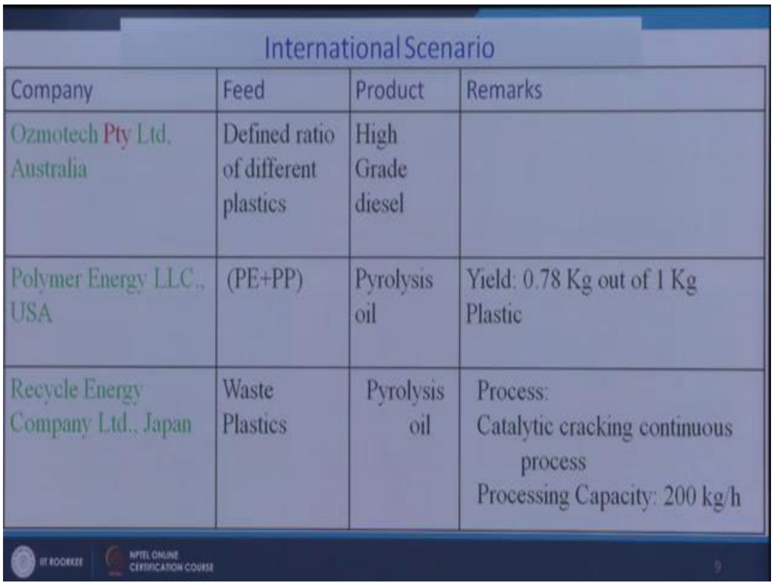

International Scenario

Company	Feed	Product	Remarks
Ozmotech Pty Ltd, Australia	Defined ratio of different plastics	High Grade diesel	
Polymer Energy LLC., USA	(PE+PP)	Pyrolysis oil	Yield: 0.78 Kg out of 1 Kg Plastic
Recycle Energy Company Ltd., Japan	Waste Plastics	Pyrolysis oil	Process: Catalytic cracking continuous process Processing Capacity: 200 kg/h

So, first is the; which more take Pty limited Australia. So, they are using they are using defined ratio of different plastics the mixed plastics they are using and getting high grade diesel see in USA polymer energy LLC. So, they are using polyethylene in and polypropylene and producing pyrolysis oil the difficulty is 0.78 k g out of point k g of plastic.

Similarly, recycle energy company limited Japan there also using waste plastics and they are getting pyrolysis oil there process is catalytic cracking continuous process and processing capacity is 200 kg per hour.

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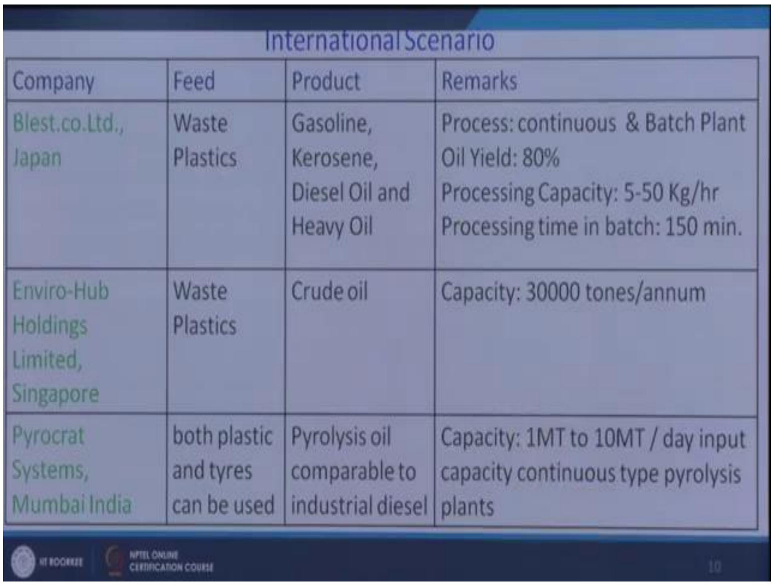

International Scenario

Company	Feed	Product	Remarks
Blest.co.Ltd., Japan	Waste Plastics	Gasoline, Kerosene, Diesel Oil and Heavy Oil	Process: continuous & Batch Plant Oil Yield: 80% Processing Capacity: 5-50 Kg/hr Processing time in batch: 150 min.
Enviro-Hub Holdings Limited, Singapore	Waste Plastics	Crude oil	Capacity: 30000 tones/annum
Pyrocrat Systems, Mumbai India	both plastic and tyres can be used	Pyrolysis oil comparable to industrial diesel	Capacity: 1MT to 10MT / day input capacity continuous type pyrolysis plants

Another example is say Blest co limited, Japan, there is in waste plastics again and gasoline kerosene diesel oil and heavy oil; that means, they are doing the separation part from the liquid oil they are giving different fractions and then this is both continuous and batch operations are used oil yield is 80 percent and process capacity is your 5 to 50 kg per hour and processing time for batch reactor is 150 minute. So, Enviro Hub holdings limited, Singapore. So, they are also use in waste plastics they are producing crude oil and they capacities 30,000 tons per annum and it is Pyrocrat systems in India Mumbai. So, both plastics and tires can be used this technologies suitable for handling both tire as well as the plastics and pyrolysis oil com comparable to industrial diesel.

So, there main target is to produce diesel from this feed stocks and capacities 1 metric ton to 10 metric ton per day and continuous type of pyrolysis plant. Now I will discuss on some research effect in India research effort put by IIP and Gayle jointly they have developed some new catalysts. So, those are suitable to convert the waste plastics 2 3 different category of products one is diesel rich gasoline rich and aromatics rich.

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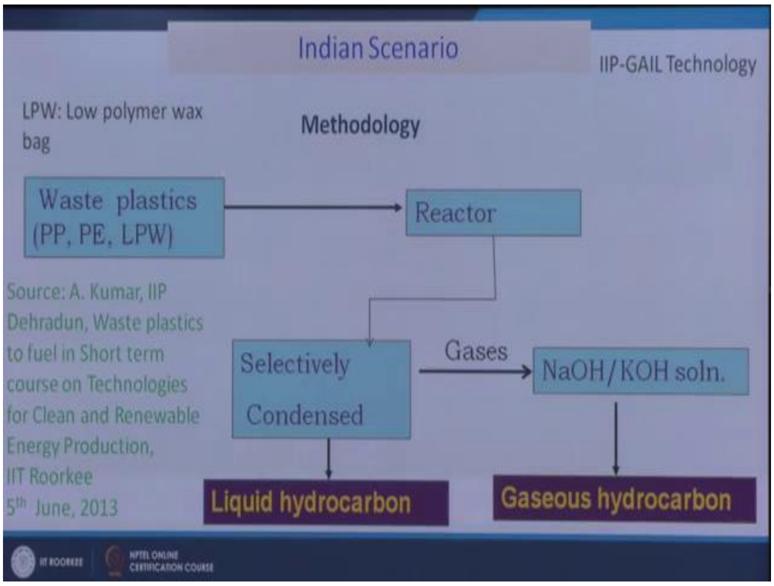

So, this is taken from the source there is Doctor Ajay Kumar from IIP Dehradun represented this in the short term course on technologies of clean and renewable energy productions and IIT, Roorkee into the 13. So, they have used PP Pand law. What is LPW that is low polymer wax bag? So, this is pre consumer waste plastics taken from industry. So, that mixed plastics are used in a pyrolysis pyrolysis reactor and then the bio vapor phase is selectively condensed and getting liquid hydrocarbon and then the gases are go going for the scrabbling and then where get it gaseous hydrocarbon after cleaning.

So, this is the flow sheets of their research and now as you have discussed or mentioned that they have used 3 types of catalyst one catalyst 2 and catalyst 3.

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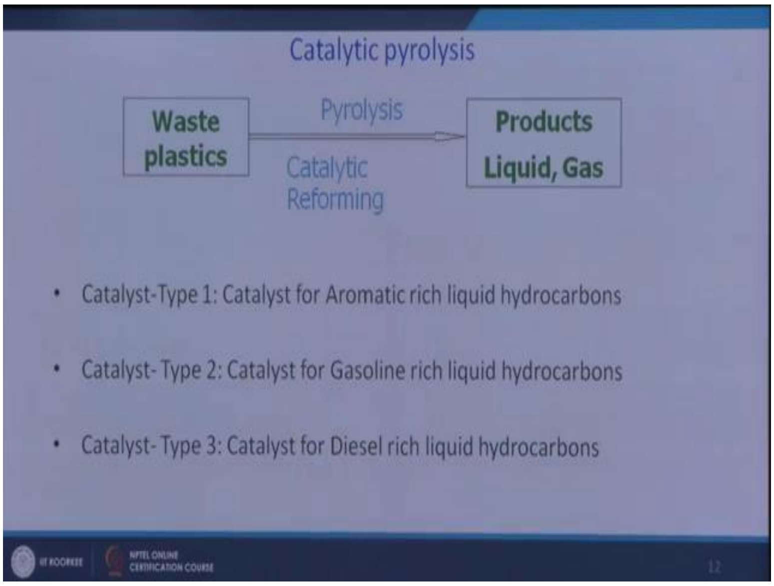

So, this catalyst for aromatic rich hydrocarbon, so here pyrolysis along with catalytic reforming, so they are catalyst are here having some property that can perform the reforming reactions and then products will be liquid and gas phase and the liquid maybe either aromatic rich or gasoline rich or diesel reach depending upon the use of catalyst type if we use one it is aromatic rich if you use catalyst 2 then there is gasoline rich catalyst 3 that will diesel rich.

So, here if waste plastics which they had taken 1 kg, PP plus PP and PW then gasoline is 700 ml plus LPG using option 1, option 2 is diesel 850 ml plus LPG and option 3 petro chemicals that is 500 m l plus GPG.

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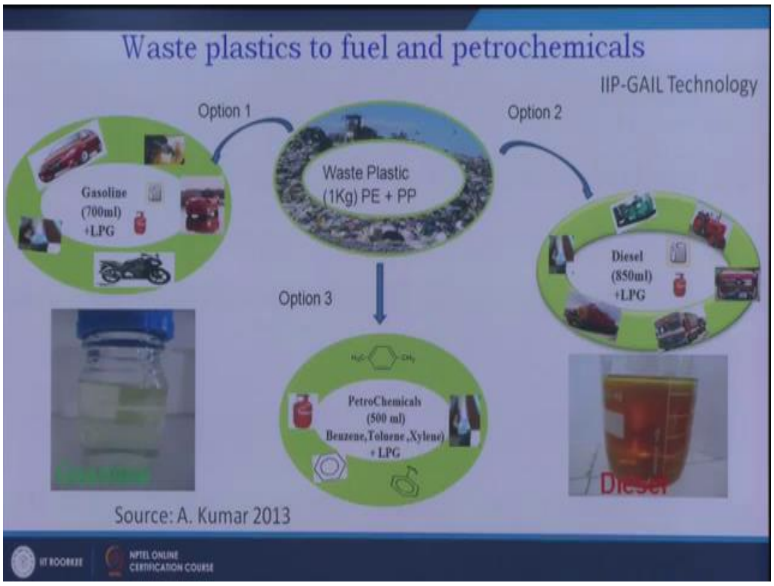

We will see now the compositions how much gasoline rich is formed and what is the weight of liquid hydrocarbons is fifty six percent of feed.

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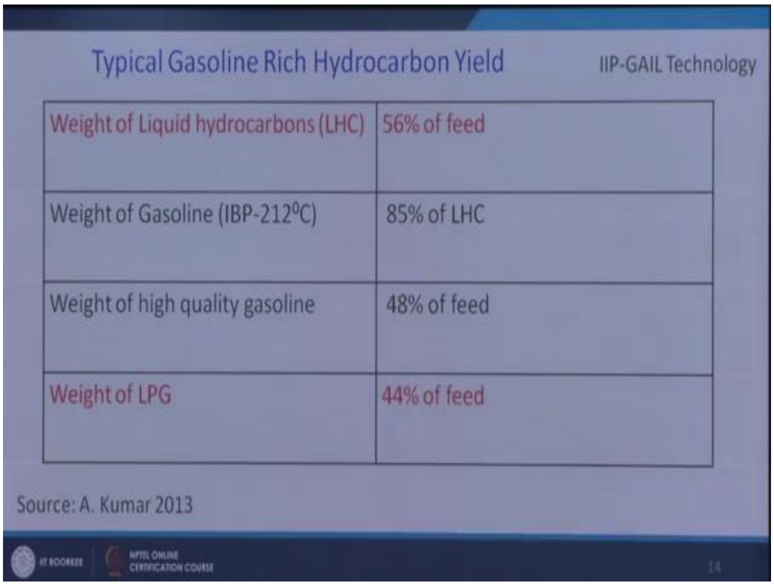

So, 56 percent of feed is converted to liquid hydrocarbons out of which the weight of gasoline is 85 percent of LHW that is liquid how much liquid is produced out of that 80 percent is a gasoline and that is also equal to 48 percent of the feed that is the weight of high quality gasoline and weight of LPG is 45 percent of the fuel that the plastics we have used.

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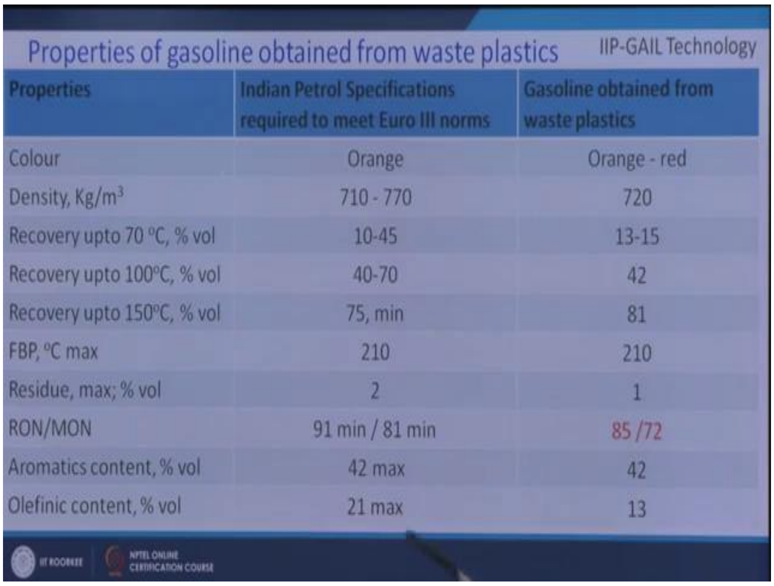

Properties	Indian Petrol Specifications required to meet Euro III norms	Gasoline obtained from waste plastics
Colour	Orange	Orange - red
Density, Kg/m^3	710 - 770	720
Recovery upto 70 °C, % vol	10-45	13-15
Recovery upto 100°C, % vol	40-70	42
Recovery upto 150°C, % vol	75, min	81
FBP, °C max	210	210
Residue, max; % vol	2	1
RON/MON	91 min / 81 min	85 /72
Aromatics content, % vol	42 max	42
Olefinic content, % vol	21 max	13

So, here the comparison of the gasoline derived by the IIP, their IIP and gel technology and the Indian specification or standards are compared here to you see this is the obtained by the research and matching with this things almost accept this one. So, RON and MON that is research octane number and mission octane number this is not in the range. So, further research is required for the improvement of the catalyst. So, that this will you can be improved.

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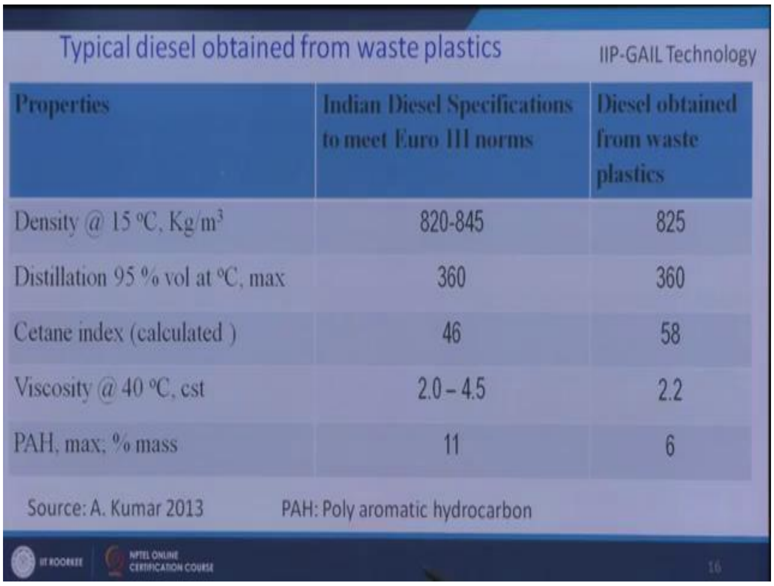

Properties	Indian Diesel Specifications to meet Euro III norms	Diesel obtained from waste plastics
Density @ 15 °C, Kg/m^3	820-845	825
Distillation 95 % vol at °C, max	360	360
Cetane index (calculated)	46	58
Viscosity @ 40 °C, cst	2.0 – 4.5	2.2
PAH, max; % mass	11	6

Now, typical diesel obtained from the waste plastics. So, using another type of catalyst for the diesel productions they have given some information shared. So, density distillation at ninety five percents so; that means, at what temperature ninety five percent product is being still that temperature is why did you hear cetane index viscosity and PAHA there is poly aromatic hydrocarbons. So, this parameter or compared where it is shown that the diesel is meeting all that quality parameters.

However, it is giving more cetane index. So, the quality of diesel is better and many other technology license are. So, say researchers have also claim that the waste plastics to diesel if it is produced then the diesel we will be having better quality and sulphur content will also be less.

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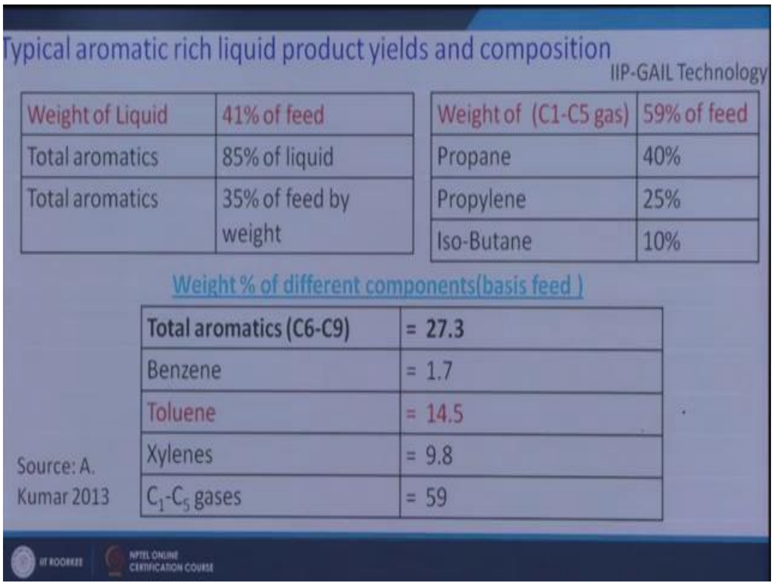

Now, you will see the aromatic compositions if the another type of catalyst is used when aromatic rich liquid is obtained in that case weight of liquid is 41 percent of the feed and total aromatics is 80 percent of the liquid and total aromatics is 35 percent of feed by weight and in this case the gas is produced that is say c 1 to c 5 molecules are present in the gas there is typical composition of LPG. So, propane propylene and is O butane the percentage are given as 40, 25 and 10 percent and the aromatic fractions which is produced in this process maximum is toluene.

So, catalyst can play major role to decide or to control the compositions of different fractions and different products now we will show some case study on Cynar plastic to fuel project.

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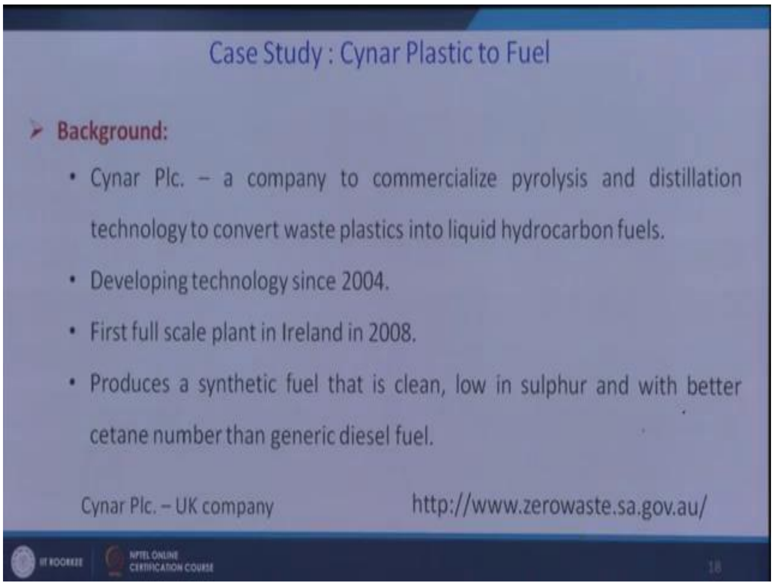

So, Cynar plastics a company to commercialize pyrolysis and distillation technology to convert waste plastics into liquid fuels and it is developing technology since 2004 and 2008, the first plant of this company was established in Ireland. So, this produces a synthetic fuel that is clean that it is low sulphur diesel it produces there is (Refer Time 22:18) company and feed stocks any sort of waste plastics can be used that is a such packaging scrap oil detergent bottles and recovered from household wastes and agricultural plastic waste those can be used through this technology and there are some difficult with the feeds tocks.

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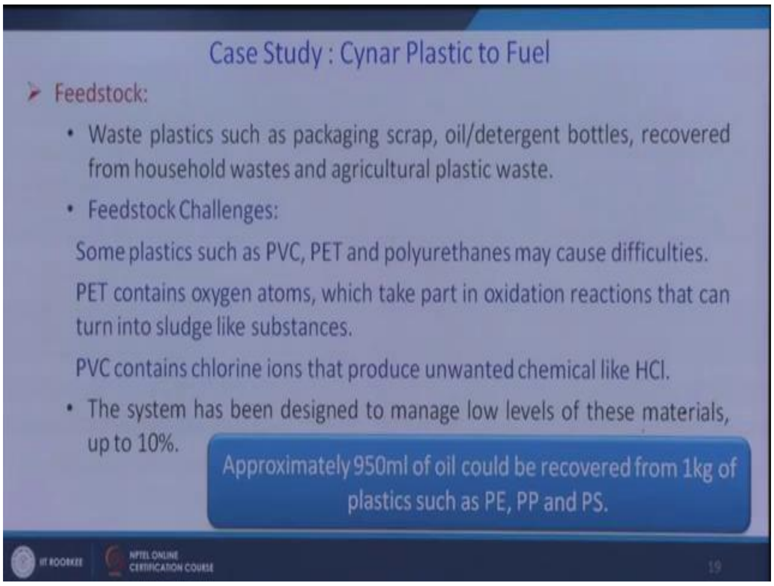

Particularly the PVC and PET are not suitable for this process already we have discussed in the previous module also the first part of this module also that PVC creates difficulty PET creates difficulty because it will form the axial PET forms different types of oxidant and that can turn into sludge like substances dioxins also forms from this all those things are there that is why this PVC and PET are not favored and the system has been designed to manage the of these compound that is PVC and PET only below 10 percent. So, up to 10 percent can be some you show how it can be managed.

So, approximately nine fifty ml of bio oil can we convert it or you can get around 950 m l of bio oil or this from the 1 k g of plastics and these technology uses the feed stocks of say 15 millimeter approximately the size range.

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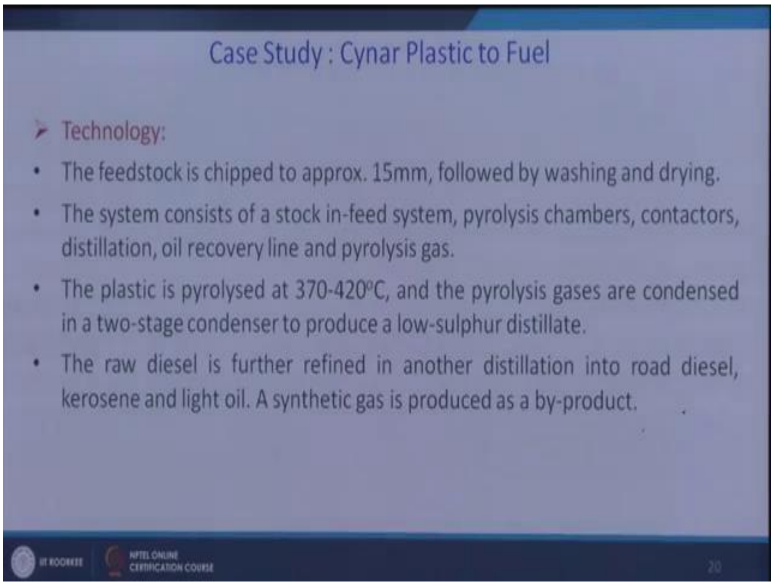

So, the material will be collected and made into proper size at 15 millimeter and then it is drying consists of a stock in feed systems and pyrolysis chambers conductors distillations oil recovery line and pyrolysis gas and this plastic is pyrolysis 370 to 420 degree centigrade temperature and the pyrolysis gas are condensed into stage condenser to produce a low sulphur distillate that is diesel we get it. And the road diesel is further refined in another distillation to make it in road, diesel, kerosene and other light well and synthetic gas is just like a LPG and these are the outputs this is the capacity is a 6,000 tons per annum of plastic and then it can produced 5.7 million liters per year liquid oil.

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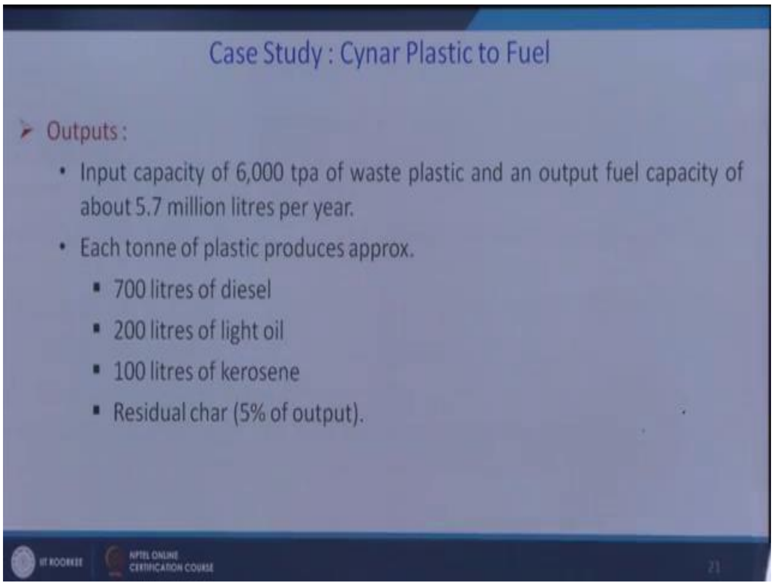

And each ton of plastic produces approximately 700 liters of diesel 200 liters of light oil and 100 liters of kerosene and residual charge is around 5 percent. So, this is one example of the waste to liquid fuel production technology through pyrolysis by Cynar plastics of fuel plastics. So, what is the benefit the benefit is that by this process the emission is reduced significantly.

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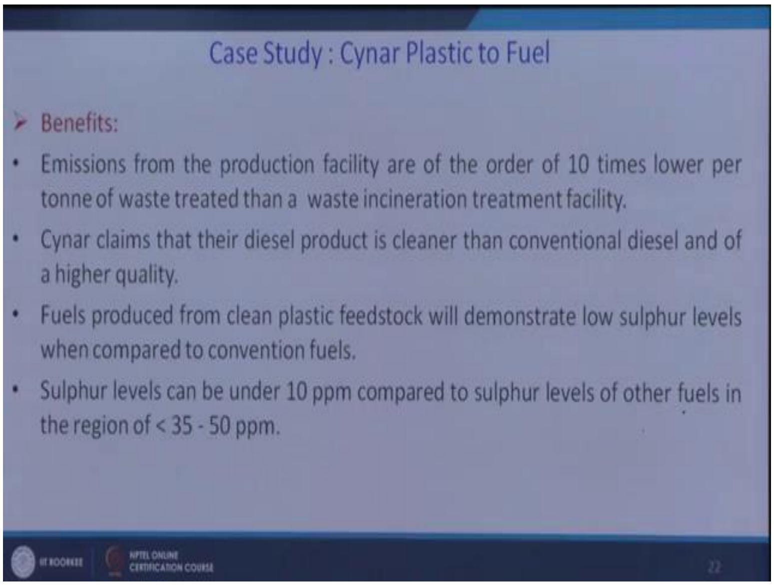

So, if the plastic surfaces through incineration and in this process if you compare that is ten timeless emission then that of incineration and Cynar claims that they are bio diesel product is cleaner than the conventional region because the sulphur content is very less here it is around 10 ppm compared to sulphur levels of other fuels in the region of region 35 to 50 ppm. So, that is why this gives every clean fuel are clean diesel. So, that is the advantage of this process.

Thank you very much for your attention.