Integrated waste management for a smart city
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Lecture 38
Thermal Treatment (Continued)

Ok, so welcome back we'll continue our discussion from the previous video, we were looking at thermal treatment.

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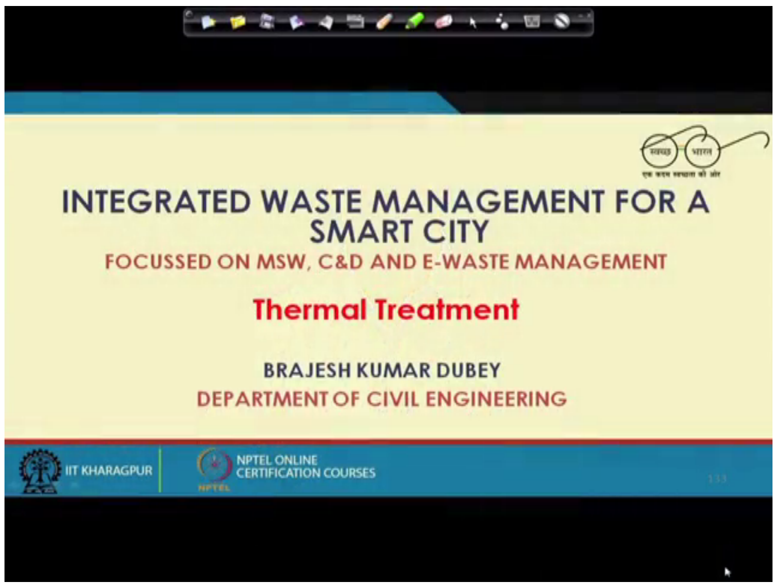

We were looking at different terminologies, we looked at mass burned, we looked at this how the system can works over there, so we'll continue this discussion into this next video where we will be looking at what is the behavior of an ideal incinerator,

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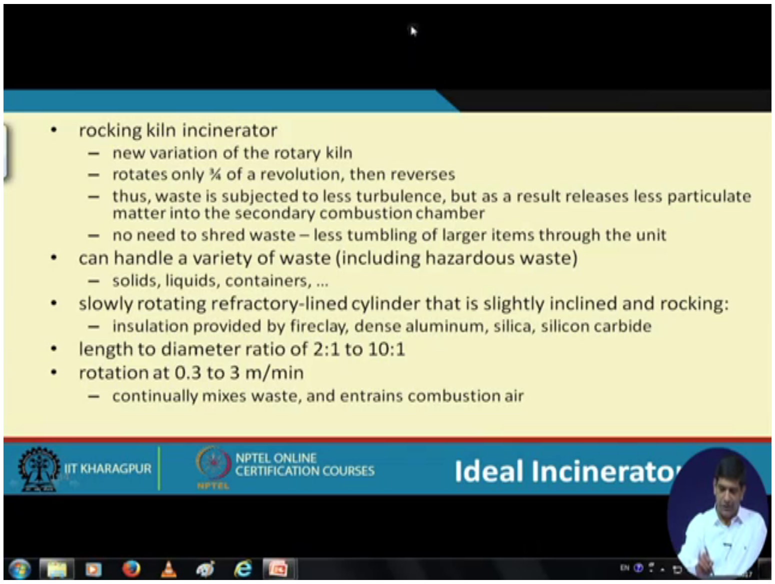

We have that this is ideal incinerator. As you can see at the bottom over here, I have this ideal incinerator we will try to identify what is an ideal incinerator. So one of these most common one is this rocking kiln, rocking kiln essentially it's a new variation of rotary kiln, rotary kiln is what you see here most of the time, rotary kiln is what is use in the cement plants as well, so rotary kiln is it rotates on the three forth of a revolutions, so rather than going it will go three forth and then it will again come back.

So it doesn't make the whole revolution, it doesn't kind of have a whole revolution it goes three forth and come back, so that is called rocking kiln, so rocking kiln rotates on the three forth of a revolution and then reverses, so here the waste is subjected to less turbulence, so that if it less turbulence actually it leads to the protection of less particulate matter, so let's pm. So if you remember we talked about time, temperature and turbulence.

So turbulence is important but too much turbulence is also hindrance, it's not good because it leads to more particulate matters. So if you have less turbulence means less particulate matter into the secondary combustion chamber, no need to shred the waste, so it's less tumbling of larger items through the unit, so it's a no need to have a waste rather going on, can handle variety of with solid, liquid containers, hazardous and all those so it can handle that.

And it's a slowly rotating refractive kiln lines cylinder that is slightly inclined and it's rocking, so the insulation property is by the fireclay and we have dense aluminum, silica, silicon carbide and all those things are here, there is a length to diameter ratio of 2 is to 1 to 10 is to 1, so it can be 2 is to 1 in terms of twice the diameter or 10 times the diameter, so it's depends on the requirement, so when the rotation is point 3 to 3 meters per minute.

So it's continuously mixes the waste, so is that the waste is mixing that means it entrains the combustion air waste is mixing so the combustion will take place so it helps in that way, so that's kind of one of the example of a like a typical, what we call ideal incinerator and combustion temperature should be between for the ideal incinerator again

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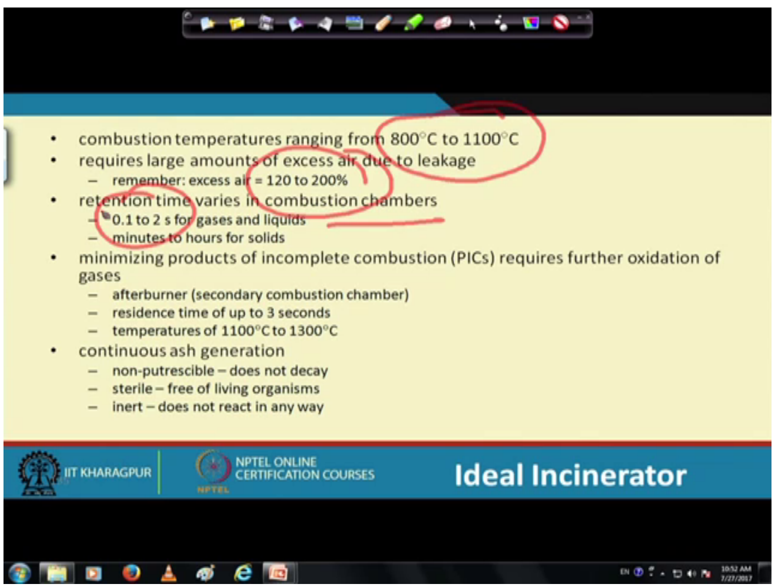

We are continuing that discussion the combustion temperature should be between 800 to 1100 degree centigrade.

And that we have already talked about that I think several times now, that we do want to work anything above thousand degree because that produces lot of air pollutants, so and then it thus require large amount of access air, so sometimes 120 to 200 percent, retention time varies in the combustion chambers point 1 to 2 seconds for gases, minutes to hours for solids so that thus happen, minimizes products of incomplete combustion.

Products of incomplete combustion requires further oxidation of gases, so it's a product of incomplete combustion, so it's requires further oxidation of gases, we can have at afterburner secondary chamber, we can have residence time up to 3 seconds temperature of 1100 to 1300 degree centigrade, so those things can be done in terms of take care of the same complete combustion, then and you would have ash being produced.

You have a continuous ash which is non putrescible, it could be sterile, it could be inert and then things if there is a use for that, it could be use for that particular purpose of course we need to look at a beneficially user rescusisment protocol for that. So then this is one of the picture of the rotary kiln afterburner

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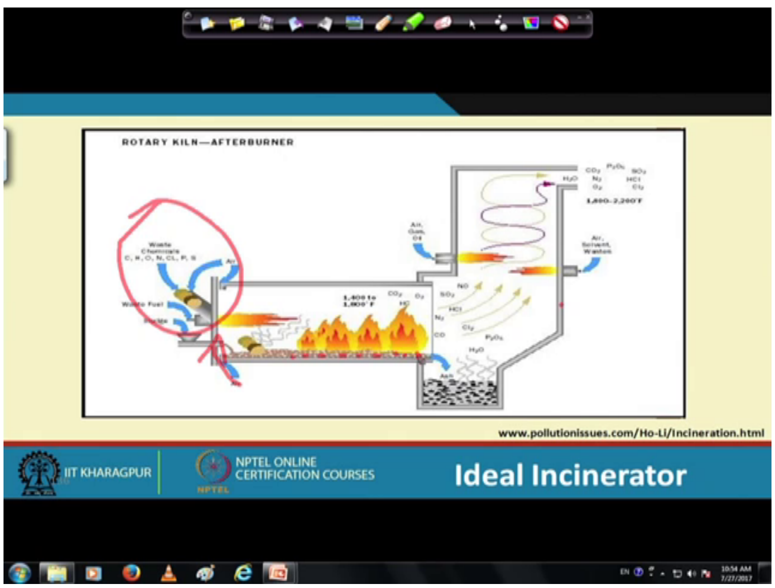

So you have this waste coming in as you can see the waste is coming in over here and it's get fared and we can insert air from this particular point.

And material is being burned as it is moving slowly and there is also a we do how we do have those rotations going on as well so it does the mixing is also going on at the same time and it's moving, it's burning we are supplying oxygen, so all those things are happening over here and then finally the ash will come down on this side, whatever is the gases and other stuff the volatile stuffs will go up and where it needs to be further cleaned and then you can dispose that.

So that's how typically a rotary kiln works for different operations.

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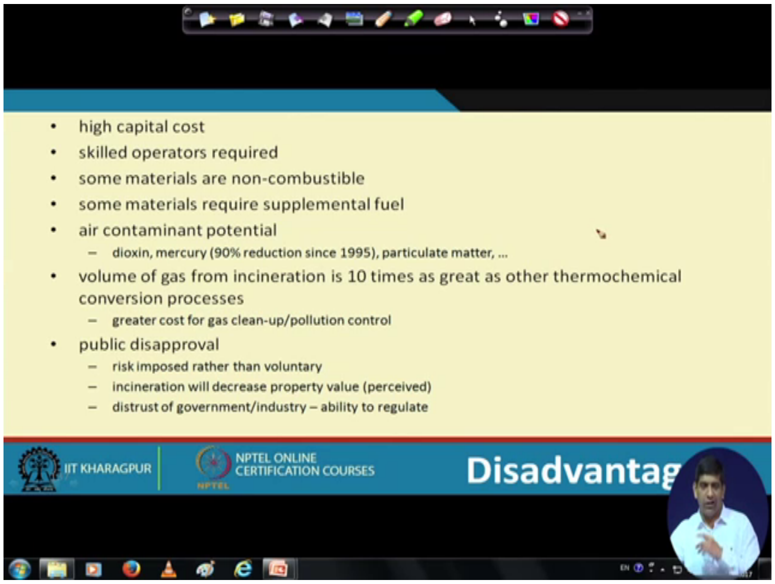

So what is the disadvantage of these kind of system, the disadvantage has been always that it's a high capital cost, the capital cost of waste to a energy plant is pretty high, so that's always the cause of concern and you do require skill man power to run this waste to energy plant, so some material are non combustive, some materials are require supplemental fuel, because there is not enough fuel to start it.

Air contaminant proper potential is there dioxins, mercury, particulate matter, those things are price there, volume of gas consideration is ten times great as well as thermo chemical conversion process, but there is a cost for gas cleaner population control, so that is also is there and the public in general is limited worried about waste to energy plant because the risk imposed other than voluntary, so they think that the incineration will decrease the property value.

Around there, distrust of government industry, because we are not sure whether the government settled up, whether it could be really walking properly, whether it could create air pollution problem and then whether the government organization will be able to helps all those problems, so there is a less trust on the government in those matter which is a kind of sag but it does happened,

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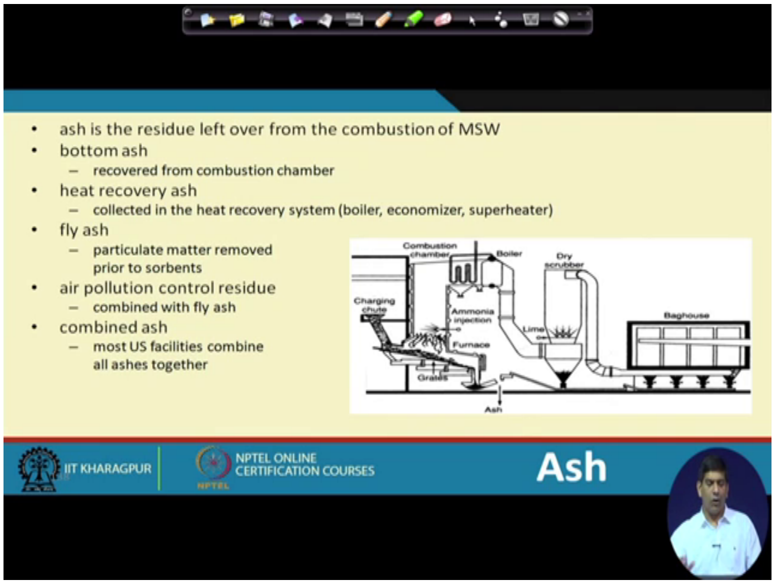

So ash is the residue left from the combustion of msw bottom. Ash is recovered from the combustion chamber then you have a heat recovery ash which is of collected in the heat recovery system which is in the boiler, economizer, super heater and all that, you have a flash which is a particulate matter, which is removed prior to sorbents, air pollution control residue,

Combined ash which is most us facility combine the all ashes together, then they manage it like that, so it all depends from plants to plants. And also what kind of business set up they have, what kind of market they are looking at so then try to prepare this material from them for the sale.

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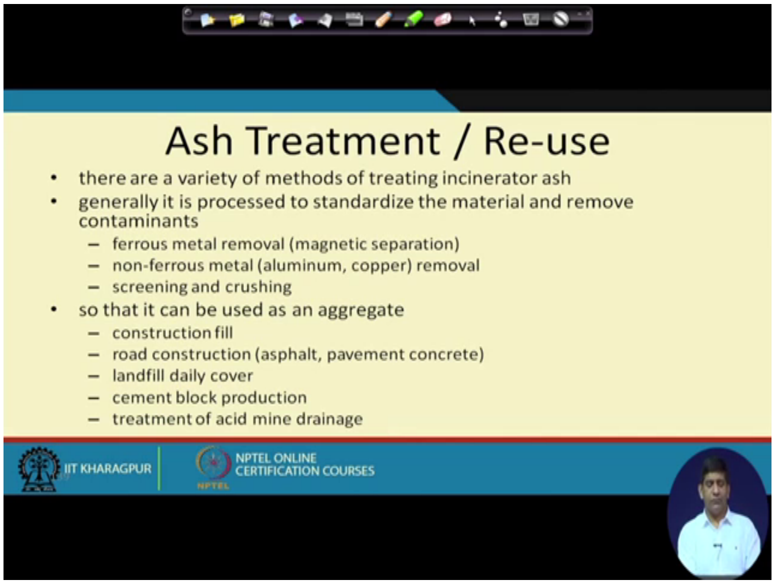

Ash could be used as a reuse, there are variety of methods for treating incinerator ash, you try to move the ferrous metal, you try to remove the non ferrous metal, so the ferrous metal could be removed, non ferrous metal could be removed, so we have the ferrous metal, non ferrous metal, screaming and crushing.

So those things can be done as well and then it can be used as a aggregate, we had done some work in this area of say almost a decade back, where we use this waste energy ash as a partial substitute for aggregate in road construction.

So and then as a aggregate it could be used in a construction field, could be used for road construction, landfill daily cover, cement block, treatment of acid mine drainage, so lot of other places where it could potentially be used for.

So that's in terms of the ash treatment what can be done with ash, so next is our flue gas.

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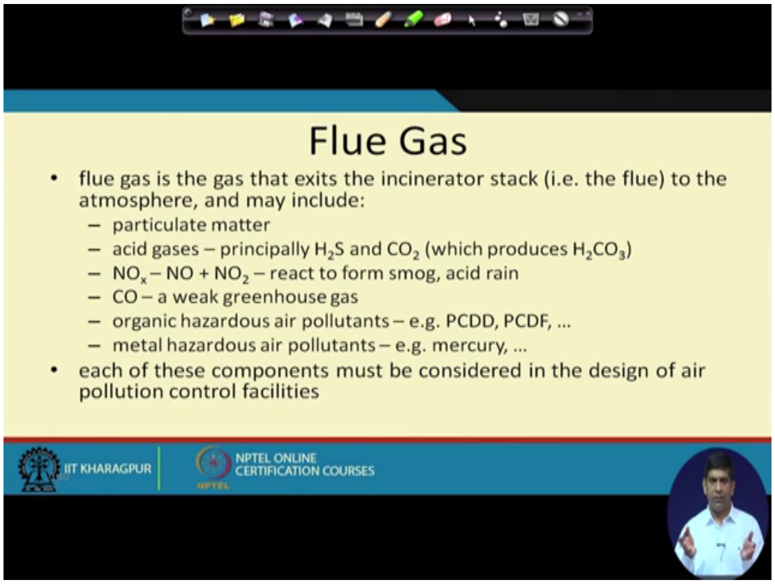

Flue gas is the gas that exits the incinerator stack which is going out that is the flue to the atmosphere and it may include particulate matter acid gases principally hydrogen sulphide, CO 2 which produces H 2 CO 3 and then NO X, NO NO 2, those things would be there carbon monoxide could be there, it could be some hazardous metal that could be some hazardous forganic pollutant.

So those things are possible but you can always get it tested out, each of these compounds must be considered in the design of the air pollution control system, so we need to design our air pollution control system in such a way so that all these different aspects are taken care of,

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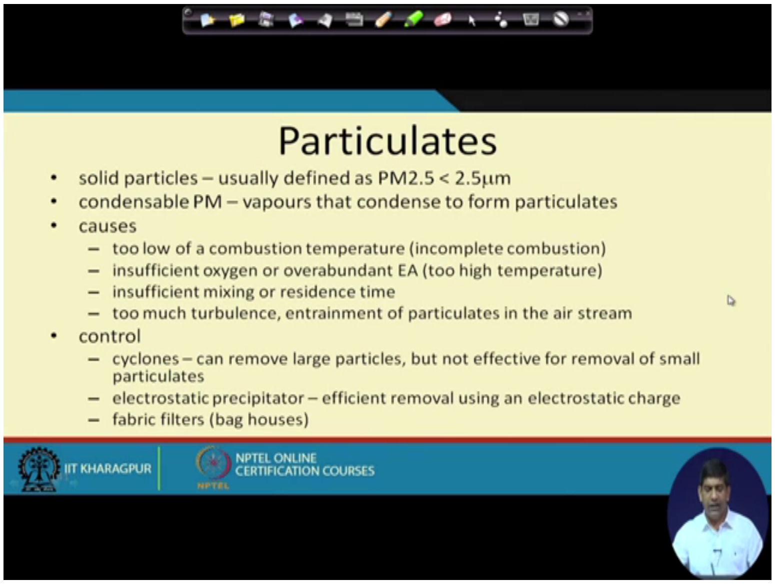

Particulates usually its defined as PM 2.5 which is less than 2.5 micron, it's condensable particulate matter which is vapors that condense to form particulates.

Because it sometimes causes as too slow for a combustion temperature incomplete combustion or insufficient oxygen or over abundant of like too high temperature, insufficient mixing in residence time and then too much of a turbulence, entrainment of particles in the air systems, all these can lead to having a particulate matter present there, in terms of the control cyclones they remove large particles, but not effective for removal of small particulates.

For the small particulate we need a electro static precipitator which is the efficient removal using electro static charge basic filter so that's the bag house that we refer to, so particulates do make into waste to energy system, especially when you have incomplete combustion and all those kind of problems.

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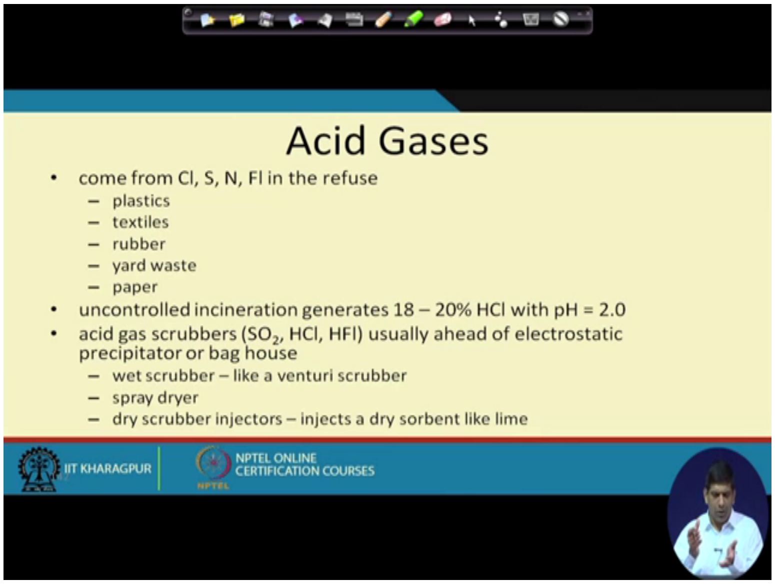

So then we have some acid gases also produced as part of the process, it comes from chlorine, it comes from sulphur, nitrogen and fluoride. It comes from fluoride, sulphur, nitrogen and also fluoride there is a typo here,

Let' see this L should not be there, so it's F in the refuse, so it's essentially coming from plastic textiles rubber yard waste and paper, so if you have uncontrolled incineration if you don't control the incineration it generates around 18% to 20% of HCl with ph of 2, so we need to reuse acid gases scrubber usually ahead of electrostatic precipitator.

Because otherwise the electricity precipitator will not because of the high acid content it will be harmful to the parts and other things over there, so we have to do a wet scrubber like a venturi scrubber, we can do a spray dryer, we can have a dry scrubber injector, injector dry sorbent lime, so different things we have to manage those acid gases, so all they are essentially acids in their gases forms and we need to kind of capture it in a triad.

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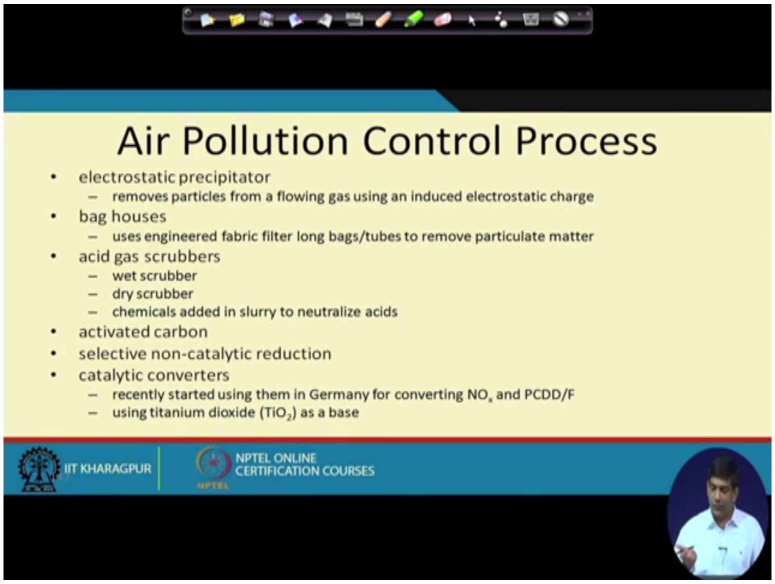

So that's like one thing about this, then in terms of air pollution control process there is a electrostatic precipitator, bag house, acid gases scrubber, activated carbon, selective non catalytic reduction, catalytic convertor, so all those things are which is a kind of typical of one like air pollution control process if you want to compare, you can compare this different components of that, so esp is actually one piece consider to any plant.

You go to like among the first few questions is do you have an electrostatic precipitator because it's costly, it's expensive to operate but it does save lot of air pollution problem, so these are some of those in terms of air pollution control system, those are different instruments which people use, so let's see what else we have here.

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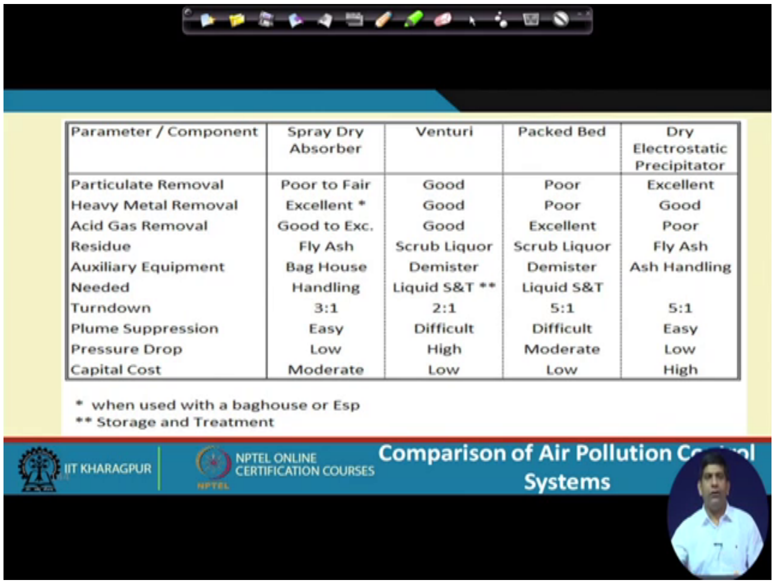

So after this one is a comparison of air pollution control system, there are different spray dryer absorber, there is a venturi, there is a packed bed.

There is a dry electrostatic precipitator, and for different categories as you can see different category has been given to us like particulate removal for the sprayed way is dry absorber, it’s kind of poor, the best it does excellent is in dry electrostatic precipitator, so then we have heavy metal is best in terms of spray dry absorber, acid gas removal is good and again for spray dry removal residue is kind of a same but it could be used in dry Esp electrostatic precipitator.

Then we have some auxiliary equipments in terms of the bag house, demister and ash handling, we have turndown, plume suppression, pressure drop, capital cost, so these are the different parameters on which these three air pollution control system have been compared and as you can see for the removal different type of contaminants, different technologies are there, so we have to kind of look at a technology which is going really work for our plant.

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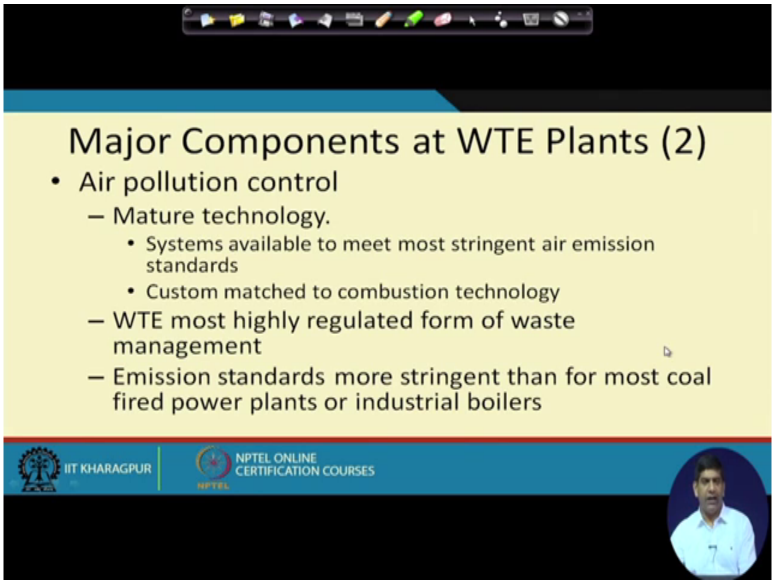

So major components of waste energy have the air pollution control, it's a mature technology now, systems are available to meet most stringent air pollutions requirement especially European countries have those with its custom match to combustion technology, so based on what kind of combustion technology are getting it can be custom made, a waste energy is most highly regulated form of waste management, it does a lot of regulation.

And because of the emission standards, because we have to make sure the emissions are not too high and the emission standards are more stringent, therefore most coal wire per plant or industrial boiler.

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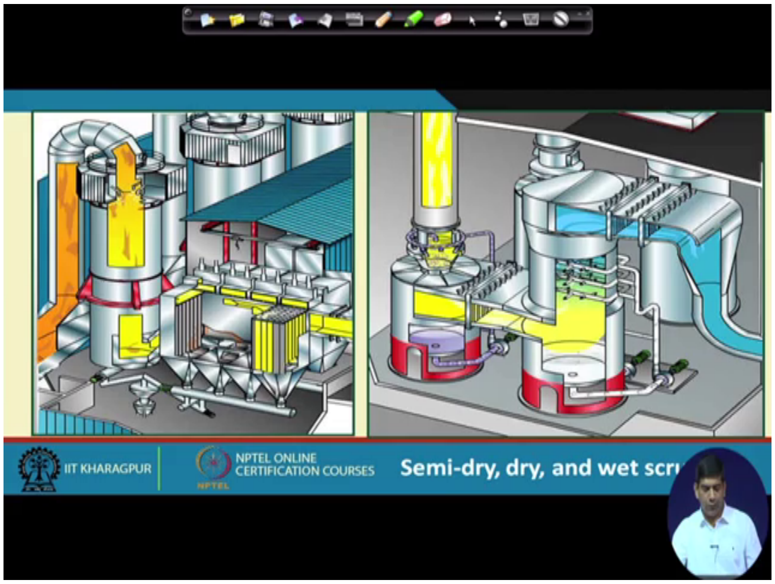

So there is a another few examples of you can see the waste being pumped and goes into these sort of a treatment system where things will get treated and then you get the residual and another things that is coming out from there.

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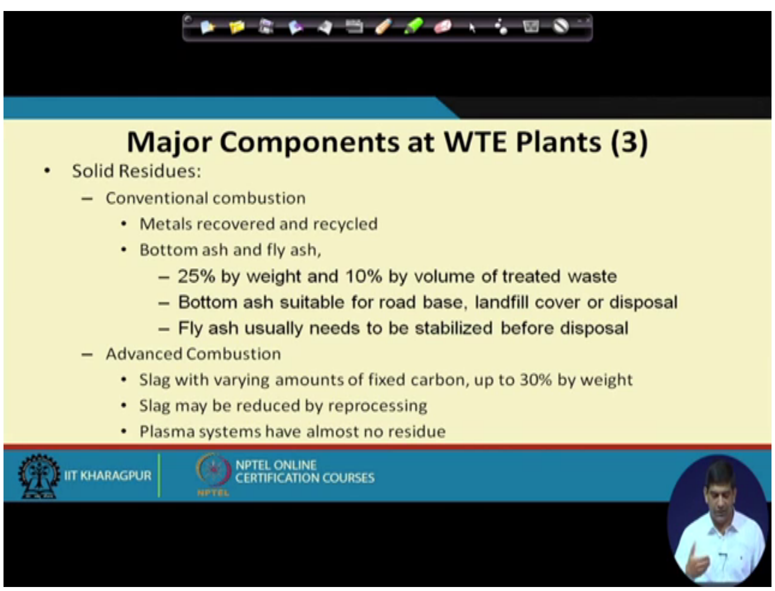

So major components that waste energy plant, it could have a solid residue which is metals and other stuff, we have advanced combustion so it's a slag with varying amount of fixed carbon up to 30% by weight, slag maybe reduced by response reprocessing plasma system if is claimed at have as almost no residue but that's not really true, there is some residue will always be there and we have seen some residue in our lab slag pilot work with this plasma system.

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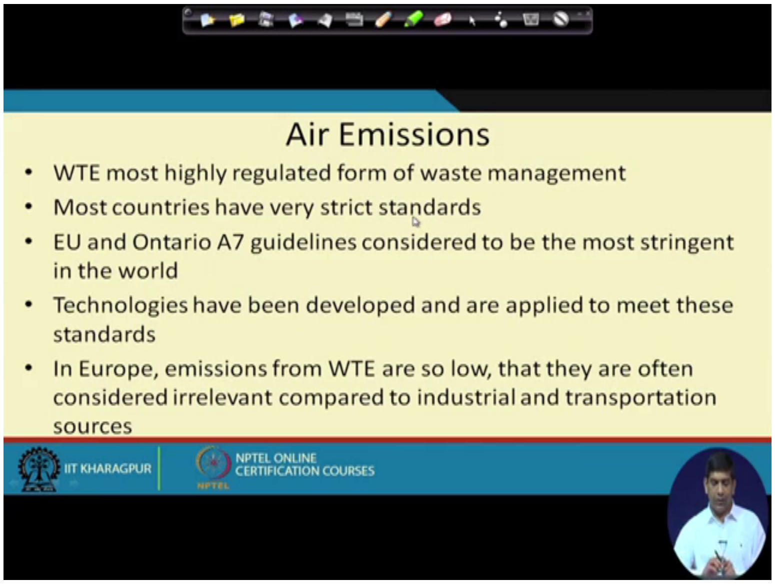

So air emissions waste energy most highly regulated as a cements in most country have a strict regulation for air emission Eu and Ontario A7 guideline considered to be the most stringent in the world, technologies have been developed and applied to meet this standard, in Europe waste energy emissions are low and they are often considered irrelevant compare to industrial and other sources, so if you try to kind of replicate that in other countries.

In other places in the world that kind of helps us in terms of trying to have similar conclusion in the Indian contest or from the Asian contest for that matter, most countries have strict standard, in India also we do have air quality standards which is we have some European union is a tough one, European union has one of the strict standard then we have Ontario A7, in Canadian system every province can go even more stricter then what the frugal government require.

So Ontario A7 guideline is considered actually one of the most stringent but the technologies are set, the technologies are out there. In Europe the emissions are so low that actually it's irrelevant compare to industrial and transportation sources, but at the same time the Indian contest we also have a waste energy plants or the technologies are out there and taken these days are said global technology, so technology from anywhere in the world.

Can be like its being procured and used in other places as well, of course there is a technology transferring those things are there, but only I have to pay money for that, but we can make the emissions low, that's the bottom line the technology has improved a lot over time so the emissions can be maintained.

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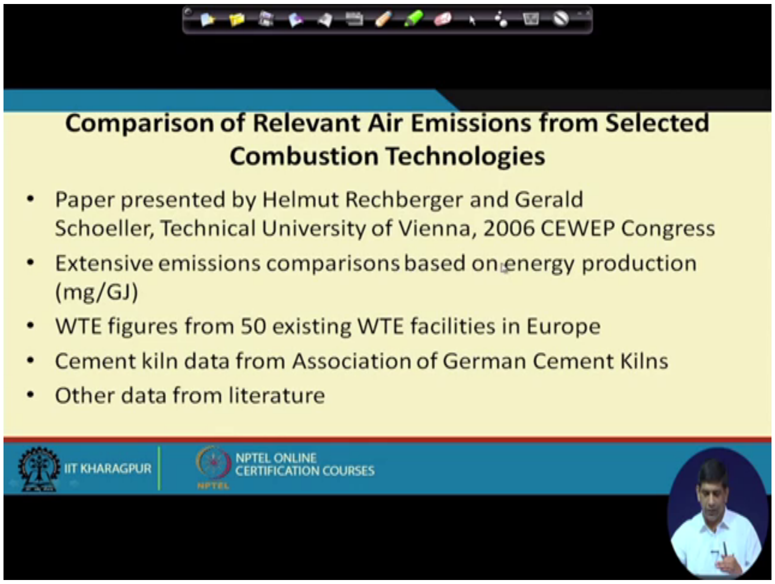

So there was a study done few years back where they looked at, I would say it's almost a decade back more than a decade back.

Where they looked at the extension emission comparisons based on energy production for different field sources and they did take waste to energy figures from 50 existing waste to energy facilities in Europe, so it does took some data from waste to energy facility, sorry here so we had the 50 waste to energy facility was taken from Europe then they got the cement kiln data, they got some other data from the literature.

And they tried to what this particular professor from technical university of Vienna group of people they try to actually compare the systems,

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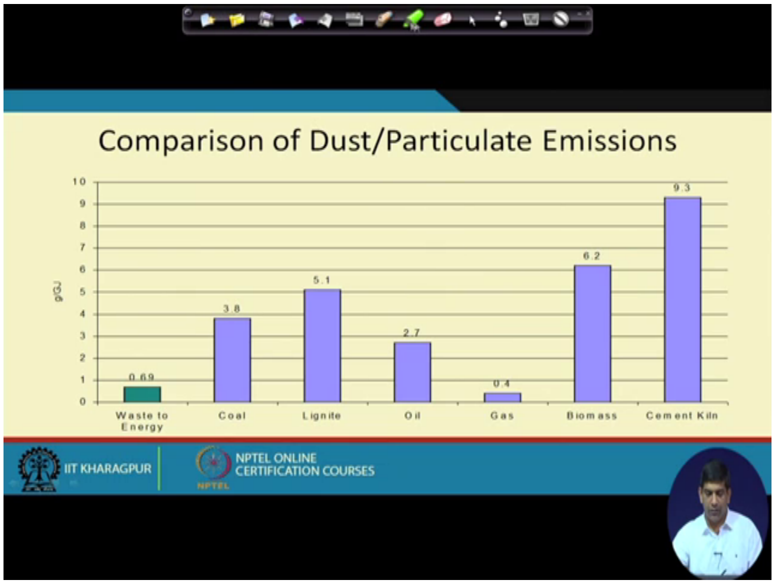

So here the first one we are trying to compare this comparison of dust and particulate emissions, so as you can see waste to energy is kind of almost 75% more than a gas, so waste to energy does fair quite while but not as good as gas in terms of their comparison of dust and particulate emissions.

But it does much better than coal, lignite oil, biomass and cement kiln, so if you look at the coal it's an on 3.8 grams per giga joule, where waste to energy does point 7, so it's nearly 20% of what you get from the coal, so as you can see because of the improvement in technology this air pollution control system as even though have many times we say this Apc Air pollution control system we can reduce the emissions coming out over waste to energy plant.

So that's what I am trying to stressful, as if you remember I think two video back I mentioned about there was an issue in Canada where in this in (())(19:46) we are trying to set up a waste to energy plant using waste tier as a fuel source but then there is a lot of fuel and cries about it because people are worried about the air pollution impact coming from that but in terms of, if you look at the air pollution impact from compare to the other emissions.

Happening from the European contest and this data this was presented in 2006, so you can think about it could be data from 2003,2004 which would be the like the latest data that could be there and so from 2004 and today we are in 2017 so it’s thirteen years have already passed and there is a lot of improvement in the air pollution control system in last thirteen years, so things have become much much better than what is being presented in this particular figures in this slide.

And subsequent few slides in terms of emission, so what I am trying to get like their the message that I want you to take out of this is waste to energy system air pollution is not of a big deal if you do things properly, if we setup a good air pollution system as required by our municipal solid waste management rules we will not have air pollution problem, the Indian contest I see more problem in terms of the wastes not having the segregated waste, having this construction.

And demolition waste this leaves and other things getting mixed in our waste stream, so that’s way the reducing the color of a value, the moisture. Moisture, one thing we do in our Indian waste to energy plant is there will be storage in the first, let the garbage come in and be in that storage you basically have a storage dumper something like that where you have the waste being dumped in here and let it set the waste of few days and we have kind of a channel.

At the bottoms of moisture percolates so whatever is actually going down and it gets collected and it’s sent for treatment like a leachate, but since the moisture counting goes down over, because of gravity the water will flow down so it reduces the moisture content, you can have the crane coming and take the garbage from this and then load it to waste to energy plant, but it’s reduces, the moisture content increases our effective calorific value.

But still the calorific value is not that high so I would typically, the calorific value is made it on 2000, 2500, something in that way and that also good waste, but in the consistency in the calorific value, that’s also very very important because when you are turning a plant, the plant requires consistency, so those are the things which should require more attention to how to make that happen, of course we have to worry about the air pollution control.

But if we do it properly, if our friends in the industry being per due diligence in this area we should not have any problem in terms of air pollution system as long as this done properly, so as you can see most of these graphs really quickly now,

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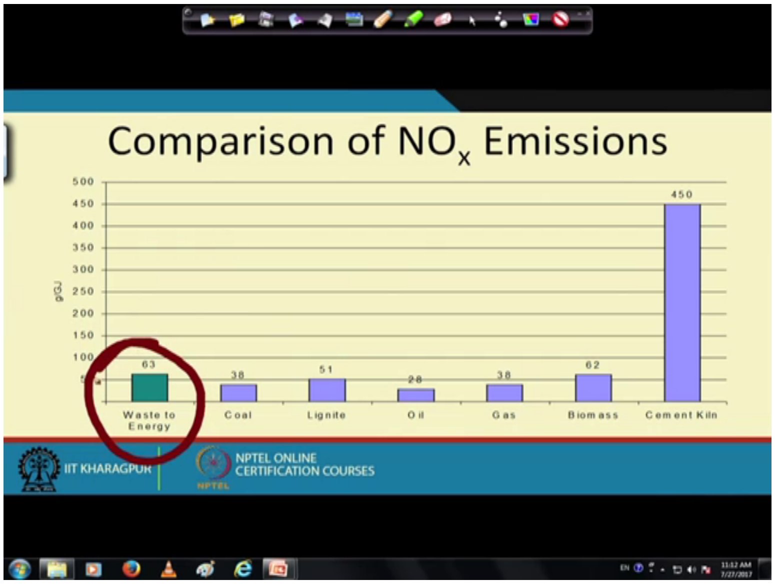

So similarly for NO X emissions again it doesn't solve the others do better than this but it's actually not that too bad is well, comparable to other energy sources much better than the cement kiln. So NO X coming out of that.

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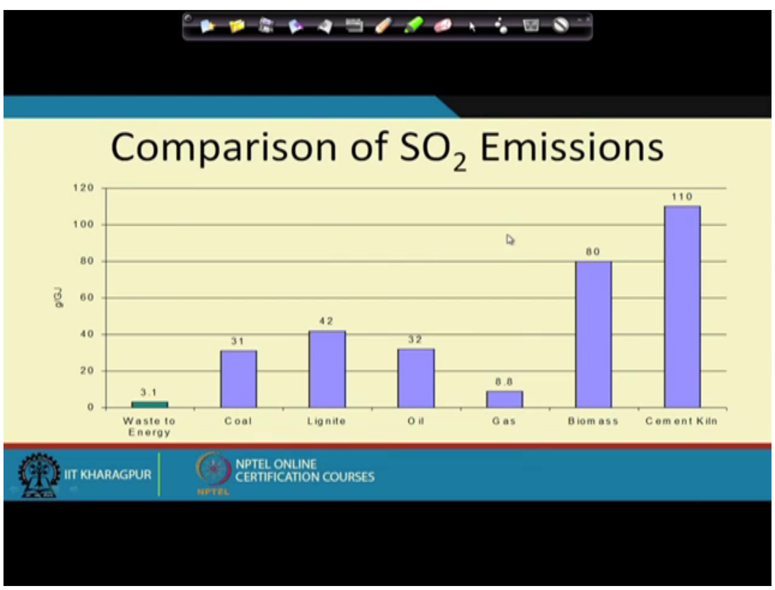

So that's another one and let's see we have a, SO 2, SO 2 in terms of SO 2 its pretty low, it's actually the lowest among all the different fuel source that we are looking at here, so waste to energy is the lowest, then we have coal, lignite, oil, gas, biomass, cement kiln, so for all the others it much higher then as compare to this waste to energy plant, so it's comparable to probably its more slightly less than gas but for others its much the difference is much high.

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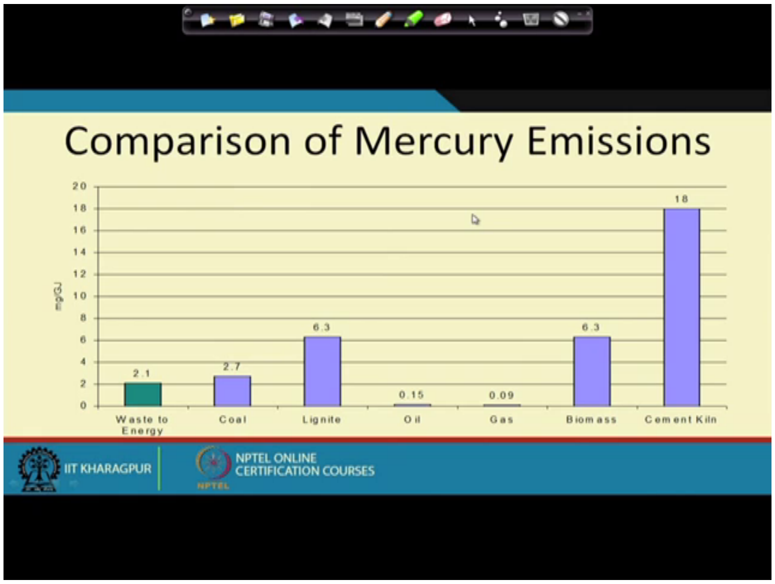

So what else we have mercury, mercury again it does fair decently well, not as good as oil or gas, but it does better for most of the other sources, again the comparison of mercury emissions from there.

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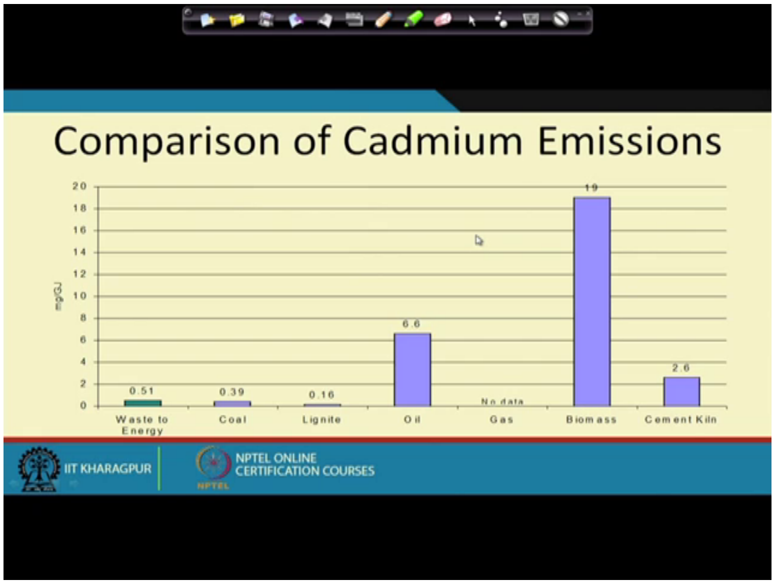

Comparison of cadmium again it does like a better than same like oil, cement kiln or biomass but for coal, lignite this it actually worse than that and then we seen being cadmium does.

Waste cadmium is used as a pigment for colors, cadmium is also used in the electronics, so you may have some waste, you have something else coming in there and that kind of periods you get that like a lid of cadmium making way to a waste stream,

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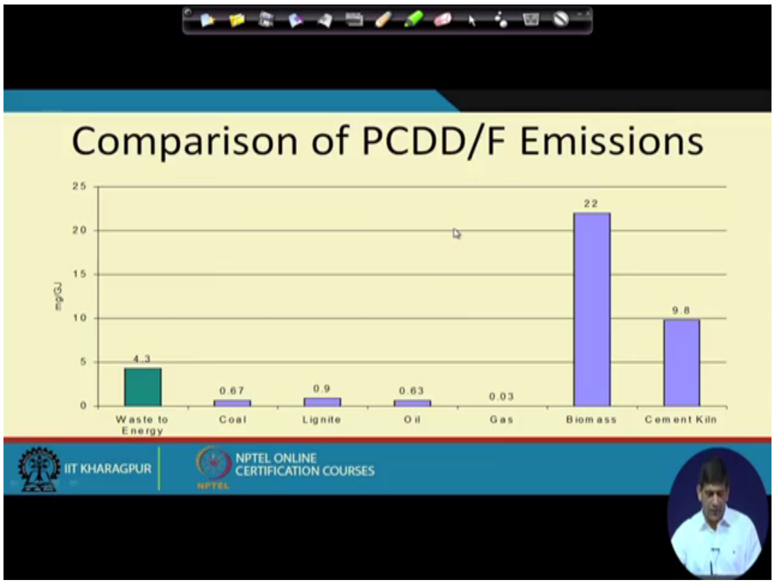

Then you may have some dioxins influence where we have this waste to energy slightly higher these are our low sorry and just a minute so here most of these are much lower.

Waste to energy is slightly higher than that but it's much lower than compare to these two numbers as well, so it's kind of in the middle in terms of dioxins and furans, so we have to be careful in terms of dioxins and furans emissions, so that being said

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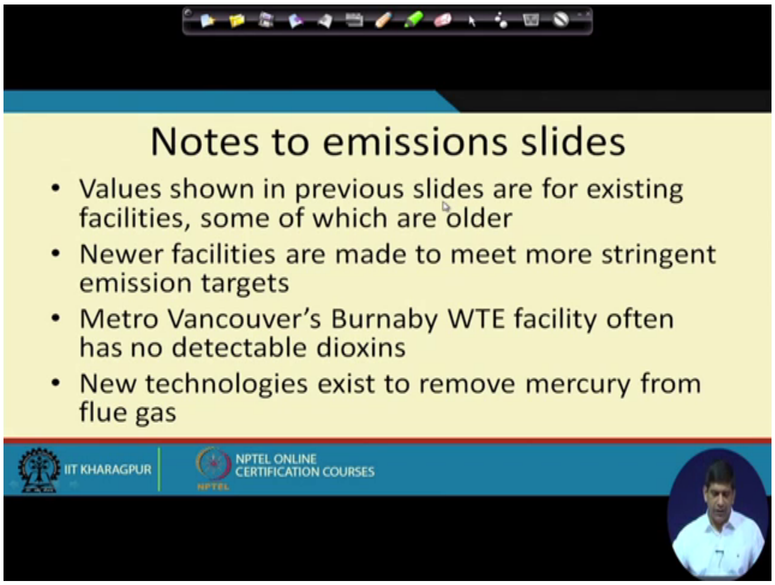

So in terms of all these emissions slides that we looked at values they are for the existing facilities, so these are for existing facility, first of all these data, this presentation was made in 2006.

And we are today 2017, so things have improved already and even on top of that the data was for existing facility, some of them which were very very old, so what I am trying to say that even things have a proved over time and even the dioxin, furans and all the other issues that you see that has also have been taken care of to most part, newer facilities are made to meet more stringent emission standard for example this Vancouver has a burned very much to energy.

Facility, they has no detection of dioxins, you saw some dioxin showing up but this particular plant are using the state of the art air pollution system, there is not so any dioxin showing up there, a new technology exist to remove mercury from flue gas, so that's another thing is there where the technology improves this can be done, so waste to energy can walk in an contest more emphasis has to be done on looking at the waste calorific value.

And how to keep that calorific value at decent number, so that we have enough heat being produced so that the plant can run, so that's the mould air pollution side, technologies out there as long as we are honest about it and we do things properly for air pollution that should not be a problem and if of course if you don't do it there always be problem,

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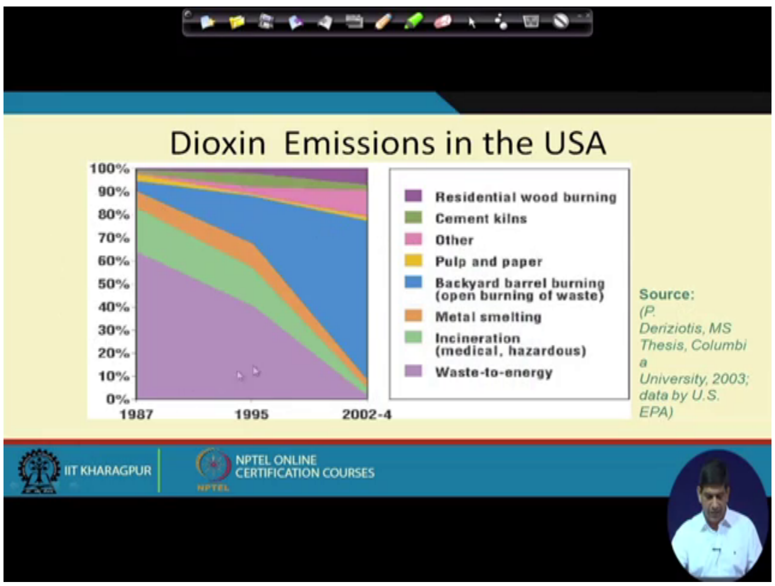

So there are if you look at the dioxin emissions again it's a little bit older data. But what we are trying to show over here is if you look at the dioxin emissions from different sources so you have residential wood burning which is on top then waste to energy is at the bottom on this particular graph and in between you have the cement kiln, others, pulp and paper, backyard barrel burning which is open burning of garbage and in metal smelting incinerators, so as you can see from 1987 to 2002 for many of these categories.

This is your waste to energy and then you have incineration, biomedical hazardous, we have the metal smelting, this is the backyard open burning of garbage part here, then some others pulp and paper, then on top is residential wood burning, so as you can see from this waste to energy was a good, percentage wise is a good source like a very high source of dioxins in 1970, let's take this off in 1987, but when we came on to 2002 the percentage has gone down much much lower.

To like a single digit, so from it on 60 to 65 percent the value has now down to almost close to zero or few percent, so that's the source, the improvement in waste to energy air pollution control system for controlling of dioxins because that's one of the important aspect, other way open burning of garbage which was all may be around 10 percent or less than 10 percent, today it's actually this is the highest cause of dioxins and furan.

And I think I told you already before there was a Unep study, United Nations environmental program study was done on this where we found this were we found that dioxins and furans are major source of them is actually opened burning, uncontrolled burning of garbage on the dump side, on the people's backyard, or sometimes on purpose, sometimes it is happening by accident, but that's the open burning of garbage is the major source of dioxins and furans.

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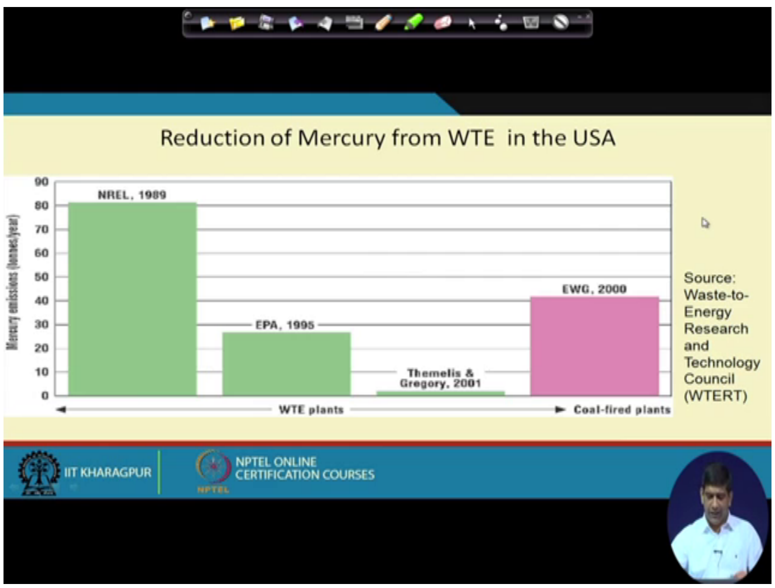

So deduction of mercury again this different like, from 1989 if you look at here from 1989 now 1995, 2001 data 2000 so it on different types of coal waste to energy plant, these three are waste to energy and the last one is called coal base thermal power plant, so as you can see we have kind of gone down in terms of mercury emissions, in terms of waste to energy where in coal base thermal power plant from the 2000 data was over there.

So basically it's says that having a waste to energy plant is sometimes even better than a coal base thermal power plant and of course it's never the worse than coal base thermal power plant, so waste to energy this in terms of the cover it's emits CO 2 like any other combustion process 40 to 60 percent is considered biogenic which Fis a part of the active carbon cycle so it's unlike CO 2 from fossil fuel this anything with a biogenic does not contribute towards climate change.

You can always debate on that whether it should be included or not but they are not included in climate change as of today, electricity from waste to energy reduces the need to generate power from other sources, it's has less CO 2 equivalent, than land filling if (30:21 you do a null Ca study) on that and then when you open study calculated to that waste to energy emits point 35 kg CO 2 per kg of waste where land fill emits nearly double of that point 69 kg CO 2.

So that's a base coming from one European data, so CO 2 if you compare with a transportation and waste to energy CO 2 emissions from the waste disposal like the transportation part landfill is this high waste to energy is right over there and from the transportation of the garbage it's over on that particular side, so CO 2 emissions for the different sectors of waste management so on that particular aspect

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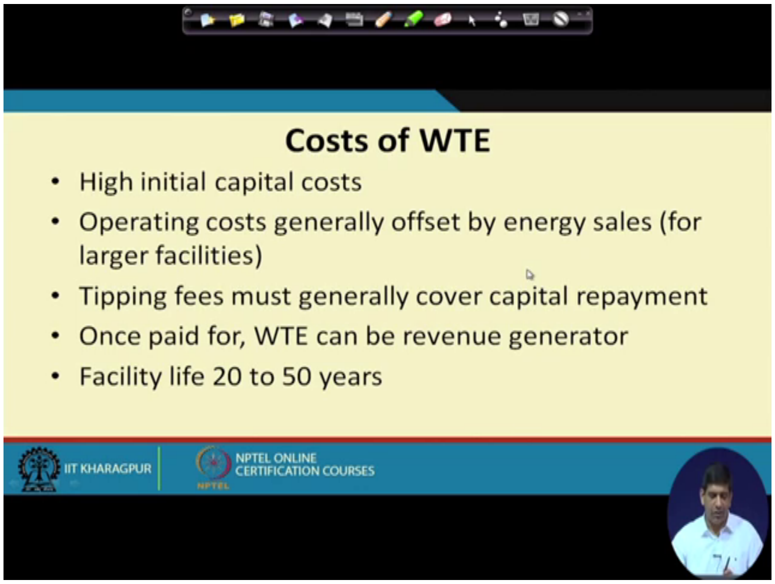

Cost is high capital cost to operating cost is also high. But it's generally offset by energy sale, if you can sale the for larger facility, tipping fee actually should cover capital repayment, so that's tipping fee generally cover that once pay to waste to energy can be revenue generator facility life usually go from 20 to 50 years, so that's you can make some money out of waste to energy plants as well.

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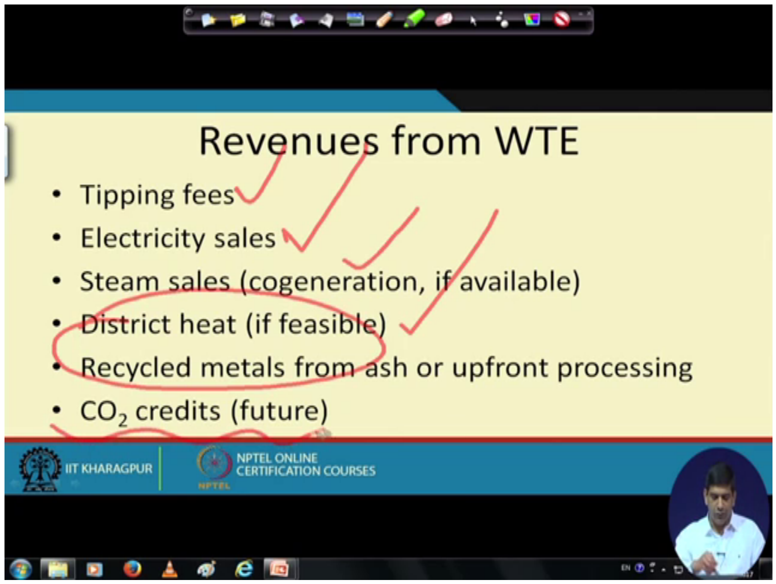

So revenues however the sources of revenue we can get it from the tipping fee, let's see one. We can get some money from the tipping fee, we can get some money from the electricity sales, steam sales, you can do the district heating which we talked about earlier, can recycle the metals from the ash, you can get some CO 2 credits, carbon dioxide credits, so those things are also possible.

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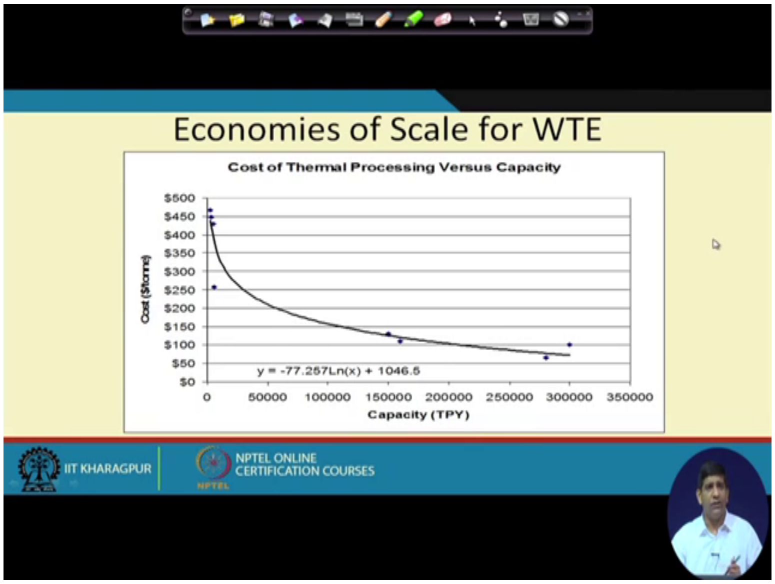

And there is always economy of a scale, like if you have this is the capacity in terms of how much terms per year and that's the cost as you increase the capacity the cost goes down.

And somewhere kind of tries to flat out, so usually if you work in this particular area, you are better-off in terms of economy of a scale.

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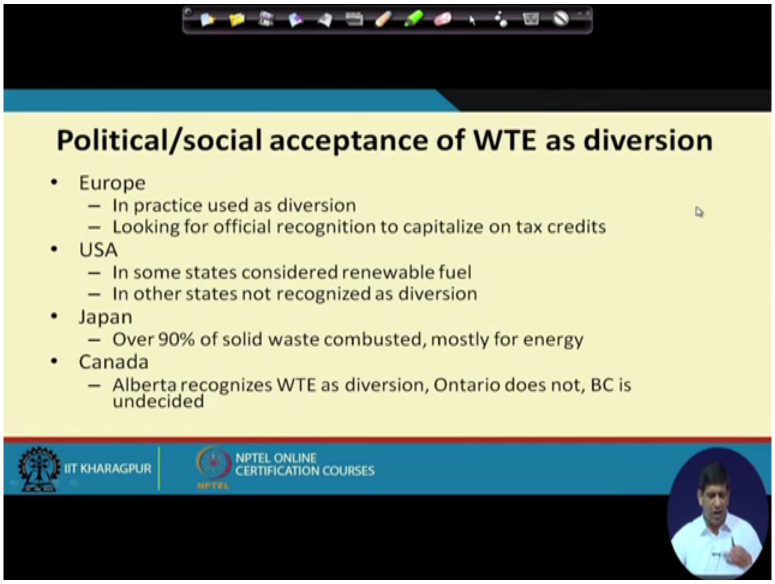

So nowadays there are acceptance of waste to energy as it a version, some places it is more some places it is less, more in European countries in India it is not getting popular as well,

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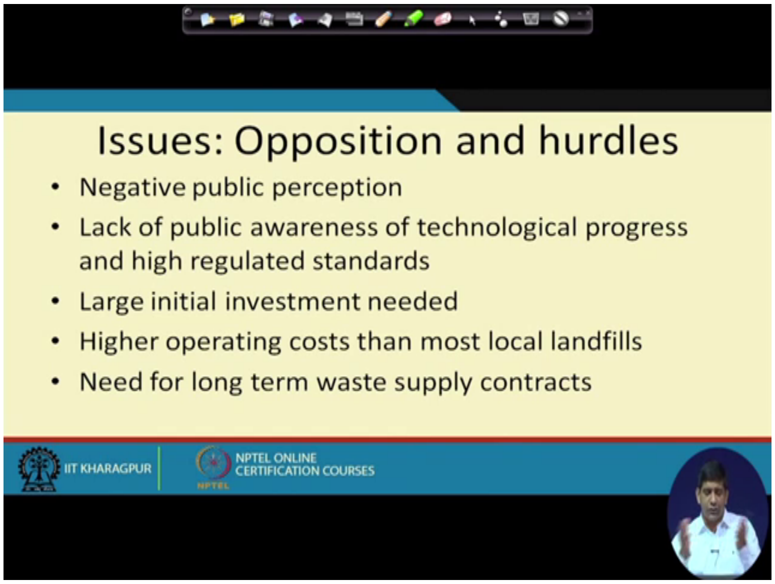

But there are some of course issues negative public perception that has to be dealt with lack of public awareness of technological progress.

Which we talked about earlier, large initial investment, high operating cost , need for long term waste supply contract, you have to make sure people the waste is supplied over there, to all there we have to look at the full cost counting and whether it's a renewable energy not a renewable energy, green house gas credits.

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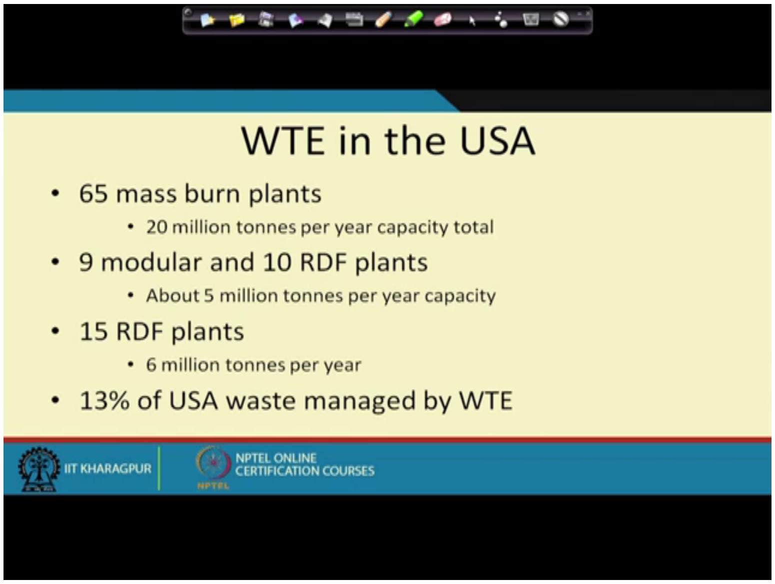

Then there are some of the examples which you can let the how much mass burned facilities are there in different places.

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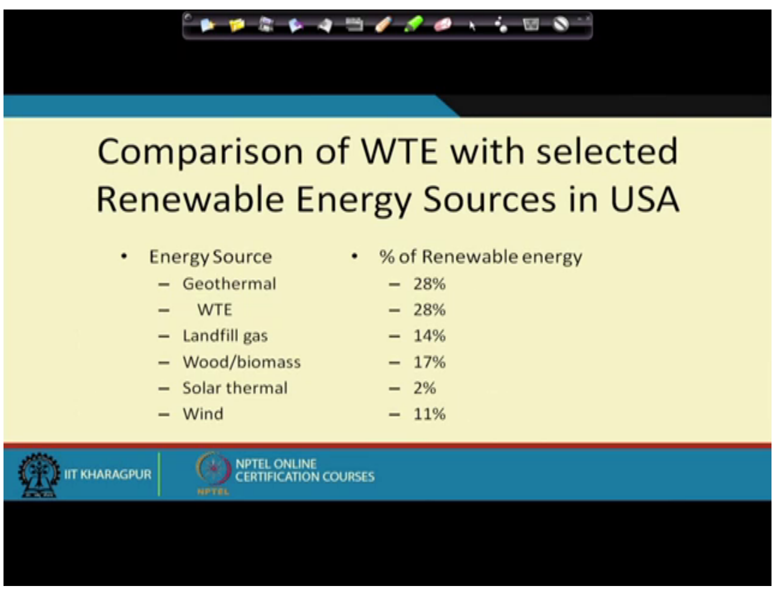

In terms of the other renewable energy source, waste to energy is nearly 28 percent of energy coming from waste, compare to others geo thermal is the same and others smaller than that landfill gas is on the 14 percent, so all together from waste management nearly more than 40 percent of the energy can come from the management sector as well,

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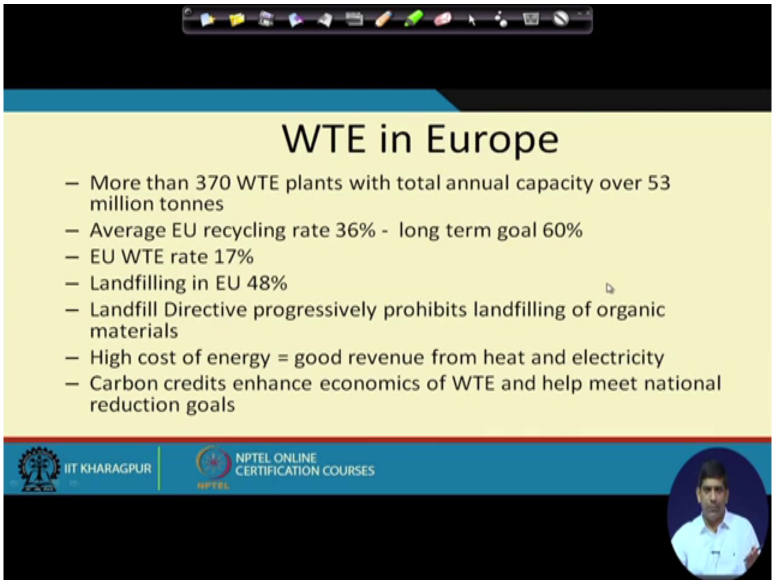

Europe lot of waste to energy plant we had already talked about that because of the landfill directive. Which is kind of forcing people to go for waste to energy plant.

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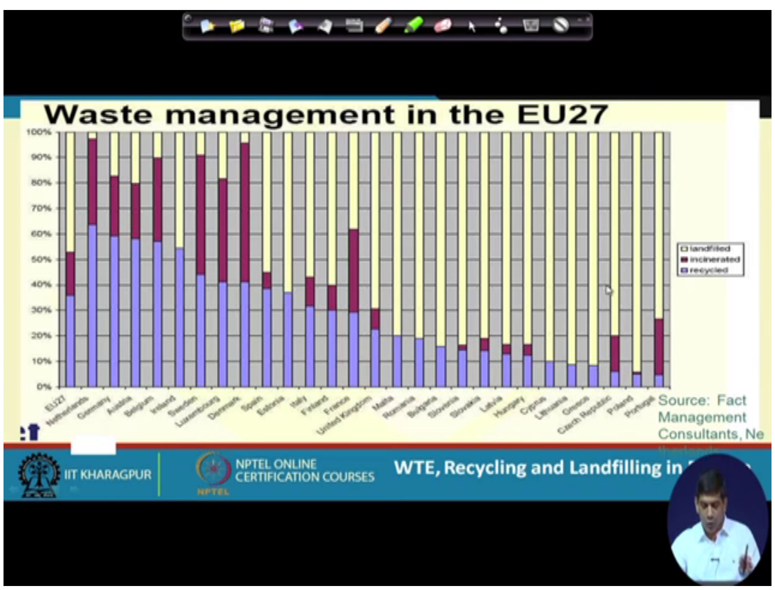

We looked at the slide earlier where as you can see more and more waste to energy plants is being the middle one sorry the purple or the magenta color is your waste to energy and as you can see on the waste left side where you have the western European countries we have more and more waste to energy being happening.

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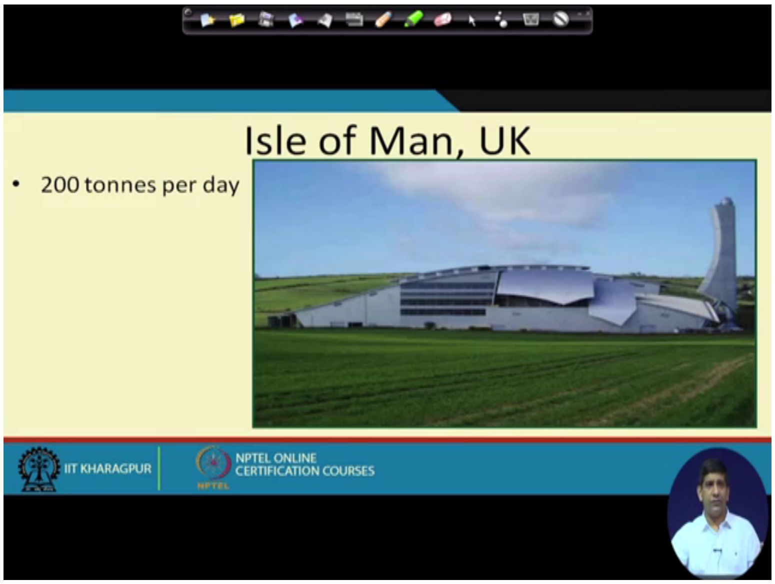

These are some pictures of all those very cool looking waste to energy plants 200 tons per day.

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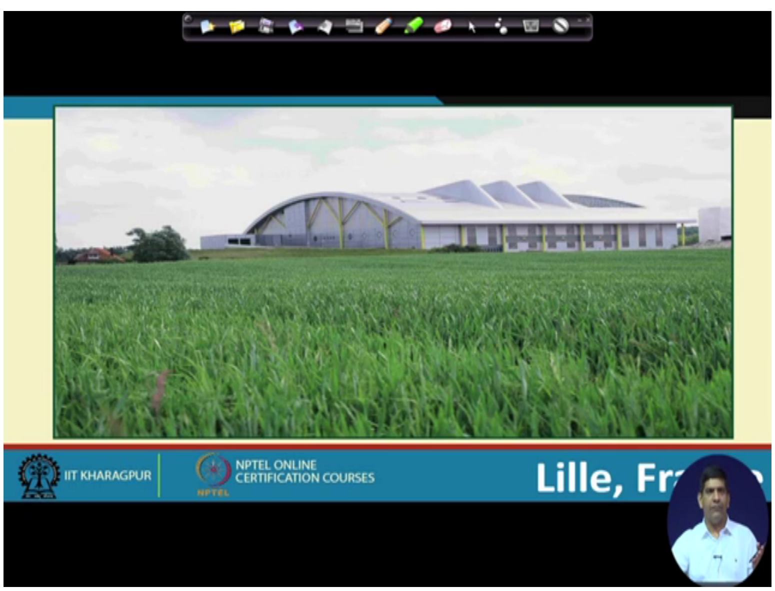

Another one you can see over here that's Lille in France,

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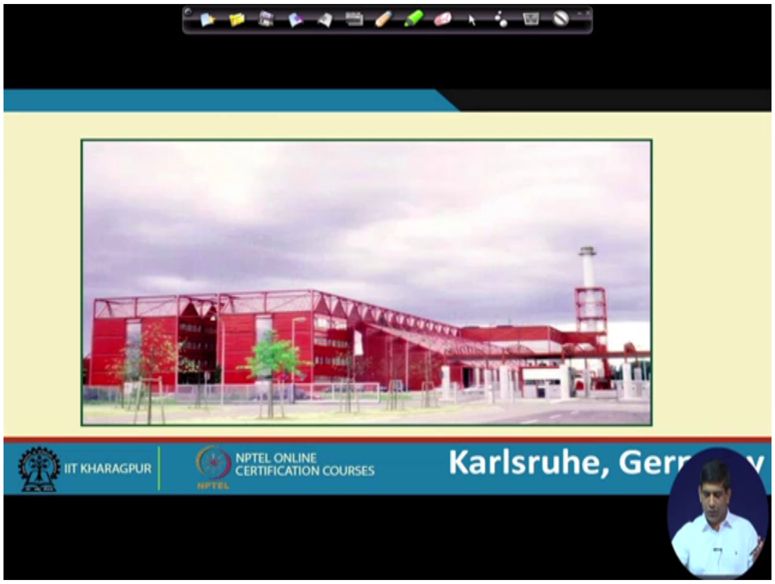

That in Karlsruhe in Germany,

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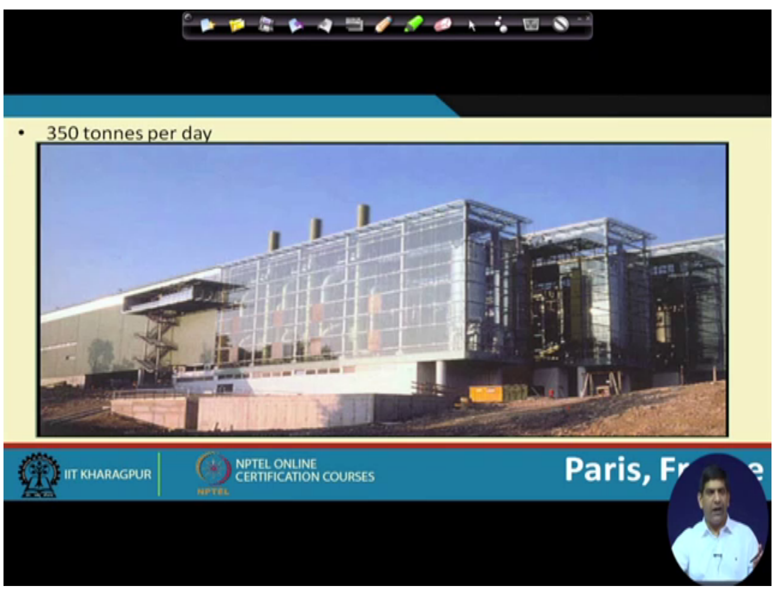

Then Paris, France, these are looks pretty cool.

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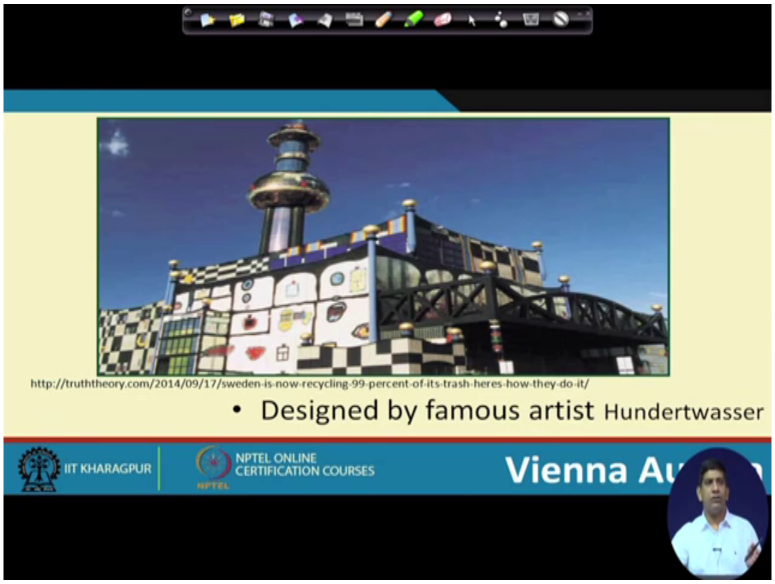

This is the most, if you go to Austria anytime in your life, Vienna do visit this waste to energy plant, it's really looks like a cool one and the middle that you see over here this is not a chimney, that's not a tower that's essentially a chimney.

So it's they made it really a beautiful one, then these are the once you can read about that, I want to wrap this up in this particular issue ok, let's stop here and then we'll continue our discussion in the next video and so we are kind of coming towards the end of waste to energy and then we'll move towards the landfill section in the next video, just few slides left for the waste to energy which I want to talk about because of, will talk about that in the next video.

So again keep working on your assignments and if you register for the exam, if you need to register for the exam, if you have not done that and also if you want to take the exam and on top of that keep the discussion mode active so that we can respond to any queries, any queries come to the discussion mode, that's the only forum wherein will be responding to so again thank you and let's have our journey together, ok thanks.