

**Plastic Waste Management**  
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**Lecture – 28**

**Plastic Waste Management - Feedstock Recycling - Pyrolysis and Waste to Energy**

So, welcome back. So, we will continue our discussion where we left in the previous video in terms of Feedstock Recycling, we were looking at Pyrolysis and plasma like a technique as well. So, in this we will kind of cover about little bit more discussion on pyrolysis the advantages, disadvantages of pyrolysis system and we will move to waste to energy which we will talk about.

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**Advantages of pyrolysis of plastics**

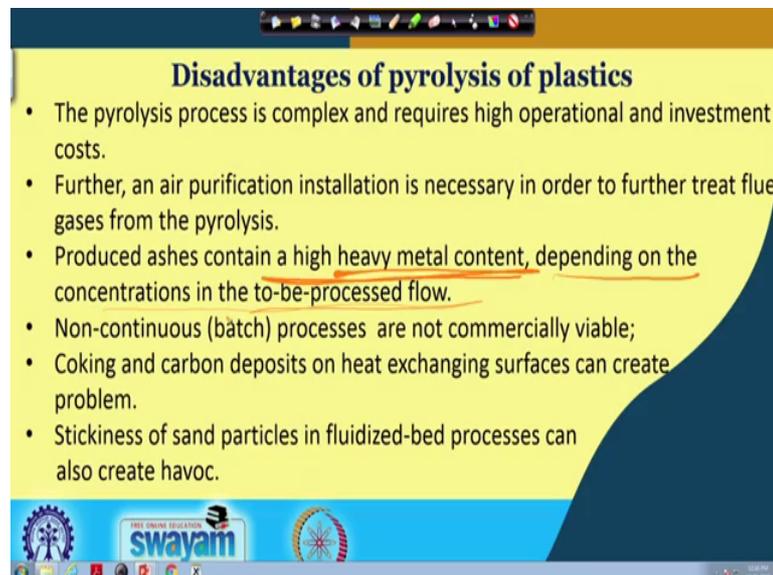
- It allows the recycling of waste mixed plastics that cannot be efficiently recycled by alternative means.
- It permits the recycling of unwashed and soiled plastics (e.g. agricultural plastics, mulch/silage/greenhouse films and dripper/irrigation tube).
- It enables recycling of plastic laminates, co-extrusions and multilayer packaging films, particularly those with aluminium foil layers that are difficult to recycle using traditional reprocessing technologies.

So, let us look at the detail in terms of advantages of pyrolysis. It one of the good thing about is that we can use mixed plastic here, we do not earlier in the mechanical recycling if you remember we had to separate the different plastic types, here we can use mixed plastic because the focus is here to do the resource recovery in terms of the energy and some products. So, you can use mixed plastic and we can even the plastics which cannot be effectively recycled by alternative means this can be used in that area as well. So, as you can see like even mixed plastic that cannot we can use which cannot find other method we can use it over here. And, we can also do it for unwashed and soil plastic like

agricultural plastic, plastic mulch is plastic mulch is used, silage, greenhouse films and drippers and irrigation tubes.

So, where anything which has some waste like some soil, some dirt at attached we can use that too although yes our the char that will be produced will have will have those impurities showing up there, but that is most for most part it will be ok. And we can do plastic laminates, co-extrusion and multilayer packaging films particularly those with aluminium foil layers that are difficult to recycle. So, this there is a lot of flexibility is there in terms of the pyrolysis plants which you can use for your application.

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**Disadvantages of pyrolysis of plastics**

- The pyrolysis process is complex and requires high operational and investment costs.
- Further, an air purification installation is necessary in order to further treat flue gases from the pyrolysis.
- Produced ashes contain a high heavy metal content, depending on the concentrations in the to-be-processed flow.
- Non-continuous (batch) processes are not commercially viable;
- Coking and carbon deposits on heat exchanging surfaces can create problem.
- Stickiness of sand particles in fluidized-bed processes can also create havoc.

The slide is part of a presentation, as indicated by the navigation icons at the top and the 'swayam' logo at the bottom. The text 'Produced ashes contain a high heavy metal content, depending on the concentrations in the to-be-processed flow.' is underlined in the original image.

So, in terms of since there are advantages there will be disadvantages. So, in terms of the disadvantages it is complex as you saw the video just before both the videos there was one from that Chinese company and then one from our lab one of the Indian research labs. So, you saw that there is there is a lot of components there it is a heavy duty it is a little bit high tech. So, it requires it is a complex requires high operational and investment cost and also the use you need is skilled manpower to run it. So, it is and you need to have air purification system which you need to make sure that air pollutant is not that high. So, that is that is needs to be treated whatever the char or the ash that you produce may end up having a high heavy metal that may create a problem.

Because, you have a high heavy metal content that you need to treat that you need to make sure that you manage that high heavy metal content material properly. Then you

have its if you do not have you cannot have a it is it needs to be a continuous process, you cannot have you cannot have its like you started stopped it started to stop it that does not work. So, it needs a continuous process and the continuous process if you do not if you cannot so, what that is mean; that means, that you need to have a good supply of plastic waste even the plastic waste there has to be a like a continuous supply of plastic waste.

So, in one way you we can say that it kind of discourages improving recycling, but you can think in that angle. But, if you look at from a practical point of view there are lot of plastic available in the waste stream which is very difficult to recycle as you just saw in the previous slide. There is a mixed plastic, there is a aluminium foil in between, there are different materials in between which it is difficult to separate all of them out and use it like one material at a time.

So, in pyrolysis system or some pyrolysis type of system it is you can mix them all together. And then it still works so, but yes you need to have that plant running all the time and you will have some coking and carbon deposits on the heat exchanging surfaces, they will create that will create some problem. Sand particles may get into fluidized bed process and then also create some issues associated with that as well. So, these are some of the disadvantages of pyrolysis process, but it is a good candidate especially for a mixed plastic.

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**Incineration**

- The practice of burning waste products in the presence of oxygen in excess amount for thermal degradation of the waste is termed as incineration.
- Incineration is a chemical reaction in which hydrogen, carbon and other elements in the waste mixed with oxygen in the combustion zone and heat are generated.  $\text{CO}_2$ , CO, oxides of nitrogen and water vapour are some of the principal gas which is produced by incineration process
- Combustion zone of the incinerator is designed within the area of  $900^\circ\text{C}$  -  $1100^\circ\text{C}$  to ensure proper combustion and elimination of order from waste.
- Temperature, turbulence, time and flow of air are properly designed for the incinerator to minimize the gas emission.

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The slide also features a video inset of a man in a white shirt speaking in the bottom right corner. At the bottom, there are logos for 'swayam' and other educational institutions.

So, other than that if you do not go for pyrolysis what are the other thing you can do with mixed plastic in particular or maybe plastic other like dirty plastics which cannot be recycled you can go for incineration. So, which is very similar to they actually essentially the same, the incineration plant that we talked about for a waste municipal solid waste or waste to energy that is kind of focused a little bit in India in last decade or so; during one of the budget by I think at that time it was mister Chidambaram was the prime where was the finance minister.

So, he had announced that India will focus on waste to energy and its special incentive for waste to energy plants were also talked about in that budget. And, since then subsequent budget until today kind of has a lot of focus on ways to energy, even NITI Aayog came up with a report on burning all the garbage; although I have some issues with that report which we talked about in the waste management class.

But in, but this is incineration is also is one aspect which can be looked into, should be looked into. And, as I said in just in the last video see we are academic people we do not have any biasness for any technology. We look at different technology, we have look at the pros and cons of different technology and then we can suggest which technology will work best in what condition because, we are not selling here any technology. So, I am not saying that this technology is good or that technology is bad. I am just saying that these are the pros and cons of different technologies and that is how and we need to evaluate. And, based on the situation some technology will be preferable than the other and that we can always discuss.

So, incineration plants waste to energy plants which is pyrolysis was in absence of oxygen, waste to energy incineration plant is actual in presence of oxygen. So, here you are doing it in presence of oxygen in excess amount where, you do the thermal treatment thermal degradation of the waste in the incineration. So, you are adding air we do not have so, as when we say adding oxygen so, we are adding air. So, we have to supply air and it is essentially combustion it is an combustion process. So, as you know combustion is an oxidation process. So, or air is required oxygen is required.

So, and incineration or there would be a chemical reaction which will hydrogen carbon and other elements in the waste will be combusted and heat will be generated based on the calorific value. Since, plastic has good calorific value so, you will have decent heat

generated and then you will have carbon dioxide CO, oxides of nitrogen, water vapour and then some principle gas. Then also we will you will you will have some traces of you will have dioxin furans and other things also coming out. Especially, if you are working at lower temperature that is why we work typically at pretty high temperature compared to other systems.

So, we are looking at 1000 degree and above 900 to 1100 degree centigrade. So, what it does its make sure that you have proper combustion and you have elimination of order; again this is a sorry it is odour it is a smell emulation of odour from waste. So, there is a and there are three major things that we need to design for temperature, turbulence, time. This is that is called 3 T's of combustion, 3 T's of combustion temperature, time and turbulence.

So, you have to have a proper temperature, you need to give a time for the waste to react waste to get combusted may based on kinetics and turbulence means mixing. So, you have to have a proper mixing of a of waste before it; so, in the mixing of waste to show that that the reaction is complete. So, you do not have incomplete combustion happening because, that will create problem in terms of a more air pollutants showing up.

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**Incineration Technology**

Numbers of options are available for MSW incineration plant technology, but only well-proven technology is executed. New technologies have developed, but they are complicated and costly which is a big problem for a developing country to execute as they lack the internal technical expertise to overcome them for which it leads to project failure.

Equipment is categorized into four core group based on their application

- Pre-treatment ✓
- Combustion system ✓
- Energy recovery ✓
- Flue gas cleaning ✓

RDF

swayam

So, incineration technology there are many number of options are there for the MSW: Municipal Solid Waste incineration plant technology and there are mass burn is most common where, you have a mass burn technology. There are new technologies that also

develop, some of them are complicated, costly for developing country to execute. But, most common is either mass burn or refused it at few and some cases you may have to do some pre-treatment as well.

So, if you look at the equipment in terms of a incineration plant you are looking at there are four major four major components of in terms of the equipment here. One is our pre treatment, then you need to have a combustion system, energy recovery system and a flue gas cleaning which are the four major categories that you have to focus on. Pre-treatment means once the waste comes in you want to make sure it does not have any component which will create problem in the combustion chamber.

So, before it goes to the combustion chamber before with waste goes took the combustion chamber we have to make sure that there is nothing in there which will create problem in terms of as small cylinders or some aerosol cans and those kind of stuff which will kind of have a blast and other stuff. So, that needs to be taken care of, also we need to take care of if we have too much moisture because too much moisture means what?

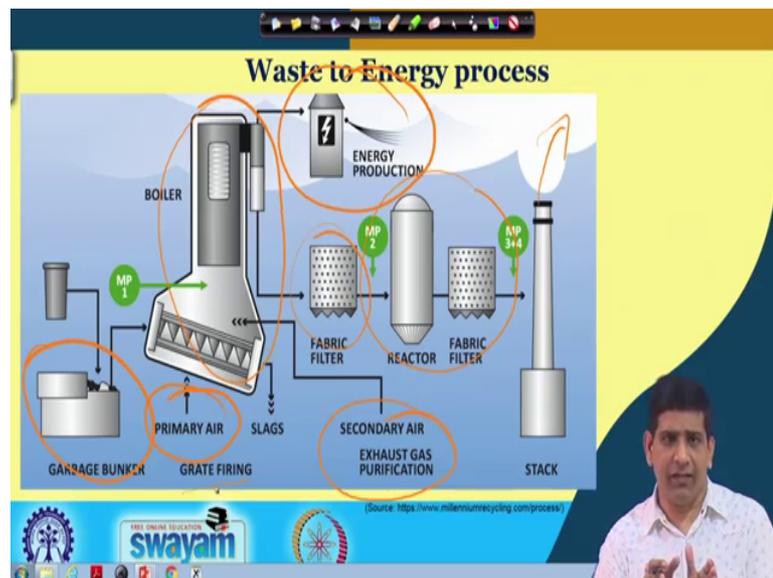
Moisture latent heat of vaporization; so, you are your net energy gain is going down. So, you do not want that to happen. So, if you have too much moisture you need to dry it. So, that kind of treatment is required and so, those and if you go for RDF facility which is called refused if you go for a Refuse Derived Fuel facility it is RDF. If you go for a RDF facility which is known as Refused Derived Fuel facility you will also can may have a pre-treatment where, you will have shredder, separators, different you want to make a homogenized size either use it as it is or palletize it together and use it in a pallet form.

So, we discussed those things in more detail in our waste management course like a general waste management which is called integrated waste management for smart cities. So, that in that course we can kind of cover more in detail, that course will be rerun again in July. So, those of you have not taken it previously may want to take it. So, there we talked about incineration in great detail, here we are just talking about how the plastic waste can be major, how can be managed using an incineration technology. So, you either you will take all those hazardous things out, you will take big make the moisture content go low or if you are going to use for RDF you will shred it.

And, rather than using a mass burn facility you will use an RDF facility which is a refused derived fuel facility which increases your efficiency of the system. But, then again you need to put all the system earlier system in place to make RDF which is has the cost as well. So, you have to do that economics, you have to this optimization which one is good either we put a system in place to make RDF and get little bit of more energy or whatever is the more energy. And, then or we just go for mass burn and we have a energy level energy gain is less, but then you do not have to put all that investment in place for producing RDF.

So, there is pros and cons of both which needs to be debated and discussed and calculated based on your situation.

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So, this is a typical waste to energy process where you have your garbage bunker coming, in it is where you have the waste coming in. So, this is your garbage getting stored over here. So, this is a huge bunker and just after this I will show you the video of Amsterdam waste to energy plant which is an animated video from Amsterdam which is in Netherlands. And, I want you to watch it very carefully and if you those of you who will travel to overseas at any point in your life and you really want to see one waste to energy plant in your life go and see that Amsterdam waste to energy plant.

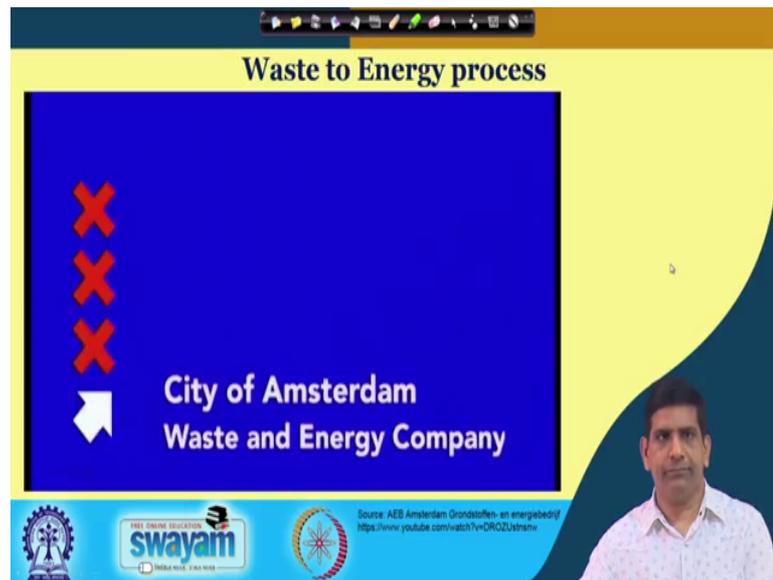
You guys may be thinking I am crazy, but since I am essentially a garbologist working with different garbage so, I get really gets fascinated by these plants and I try to visit

them. So, I have been to Amsterdam plant two times already and because and every time you go there you learn something more. So, it is so, this is we will we will see a small video on that after this slide. But, this is a garbage bunker where the waste is getting into the boiler which with waste is getting fed in to the boiler. Then you apply air through you there is an air supplier, you have a great firing happening inside this stuff where, the waste is being treated. And, once it is treated you have the; you where the heat is used in the boiler for energy production. And, then air pollution the; this coming out goes through your fabric filter and goes through some other reactors and other filters.

And then finally, it goes up from this stack outside whatever is air pollutant after getting through the air pollution control system. You also have some secondary air for exhaust gas purification and all that. So, this is how a just a very quick it is a very simple sketch for a waste to energy plant. So, essentially you have a feeding system, you have a combustion system, then you have an air pollution system. And, the heat generation will go into the boiler, from boiler to electricity generation, you can use the heat by itself by for house heating which is also called district heating system. So, that is kind of gives you a overview of a waste to energy process which can be used for plastic waste.

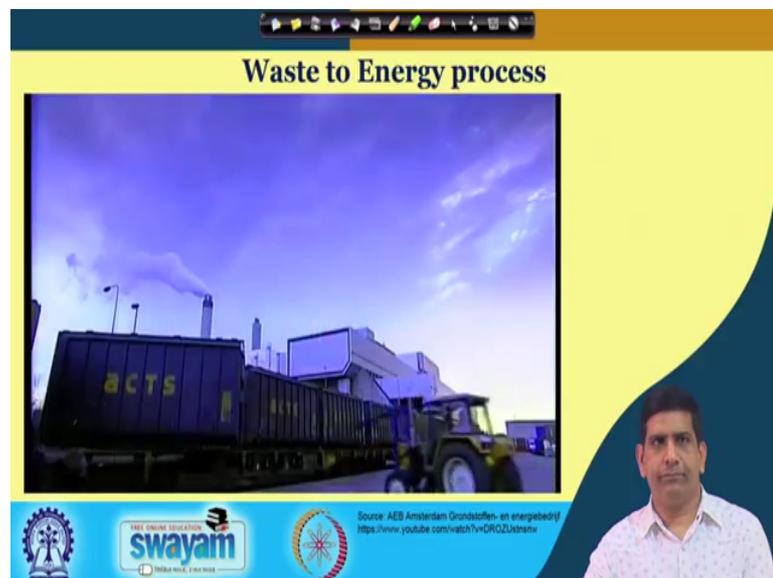
Again here we can also use mix plastic, we do not have to separate PET HDPE LDPE PP and all that, we can use mix plastic as we could use it in the in that pyrolysis plant. So, let us I think we will have a quick like you go over this video and again I will keep quiet, I want you to watch it. It has audio which will go through the whole process and once you go through this we will discuss little bit more. And, in case you want to learn more about waste to energy as I said there are resources available. One of the resources is our my NPTEL our NPTEL course which is already you will you can find YouTube videos of that and you can look at that waste to energy processes and little bit more detail.

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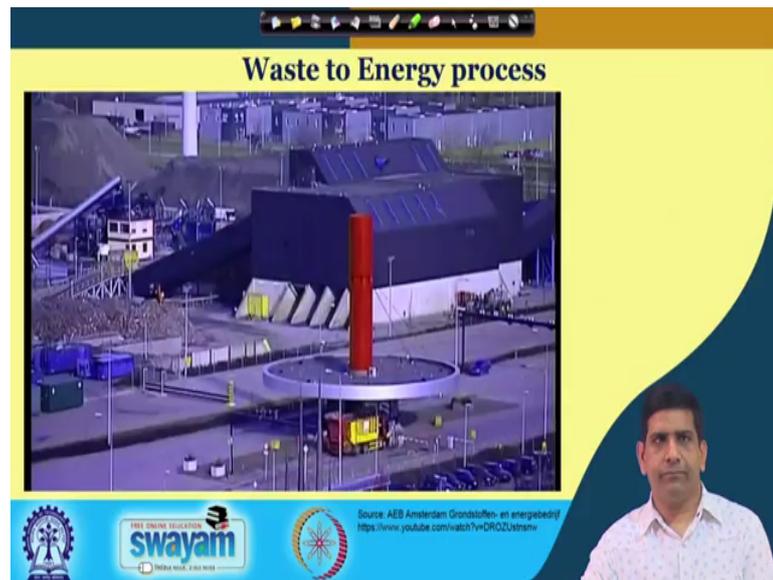
So, let us look at this video and then we will discuss the component of it.

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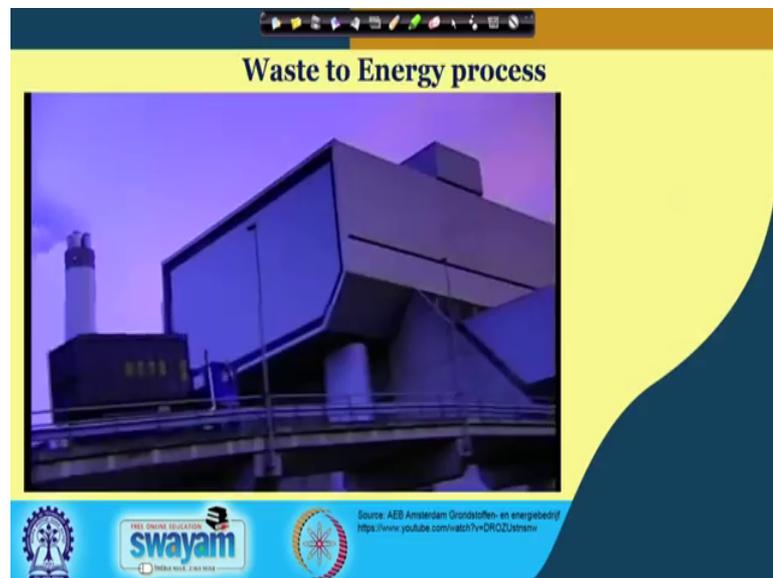
Welcome to the waste and energy company in Amsterdam.

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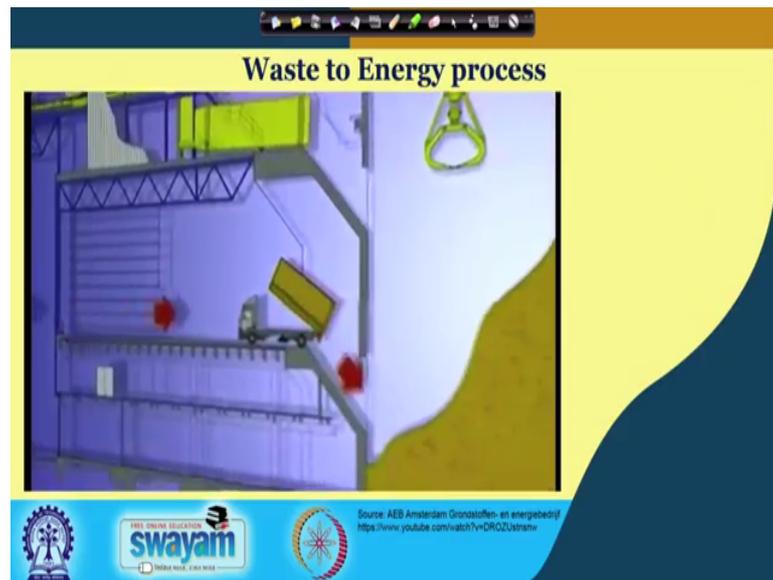
More than one and a half million tons of domestic and commercial waste is processed here, each year on 6 incineration lines.

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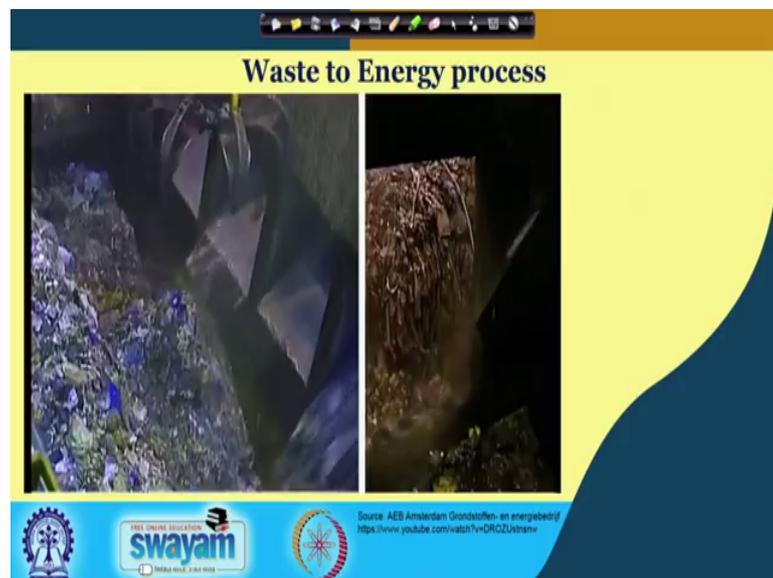
Waste lorries and trains bring in the waste.

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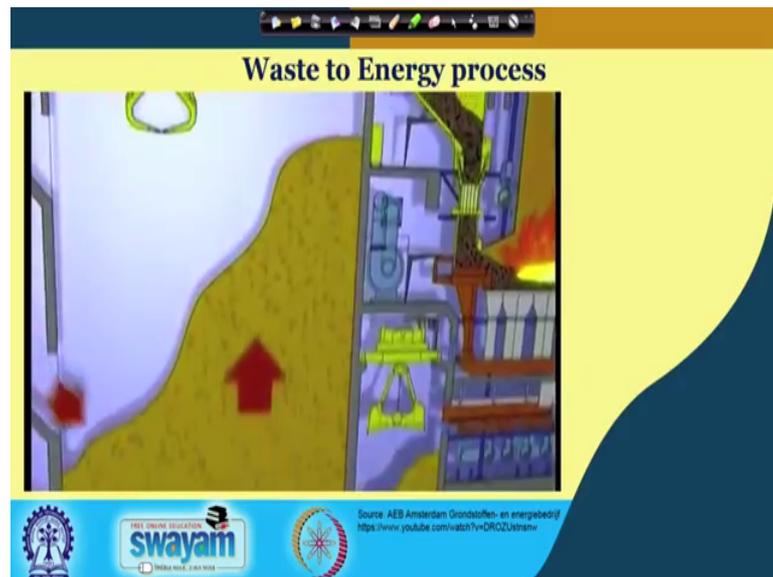
It is important for optimal incineration that the waste is of a uniform quality.

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This is why it is mixed in the waste bunker.

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Large grippers then transfer the waste mixture into the hoppers of the furnaces.

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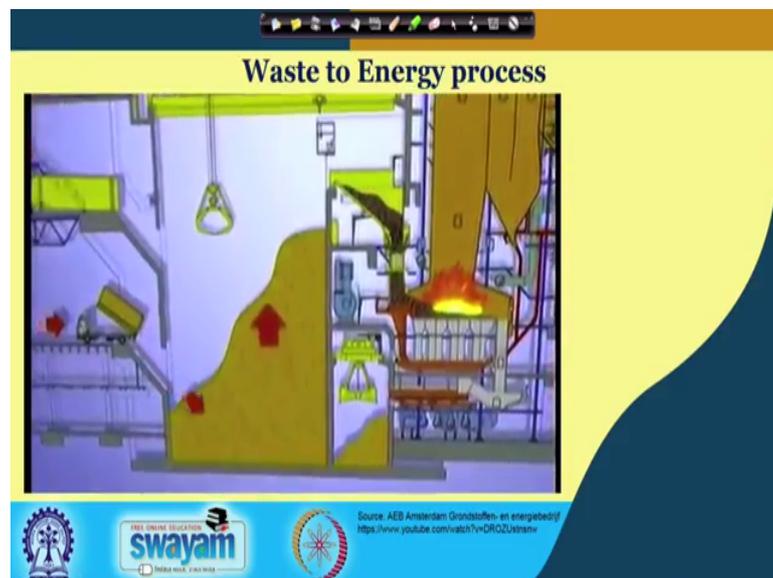


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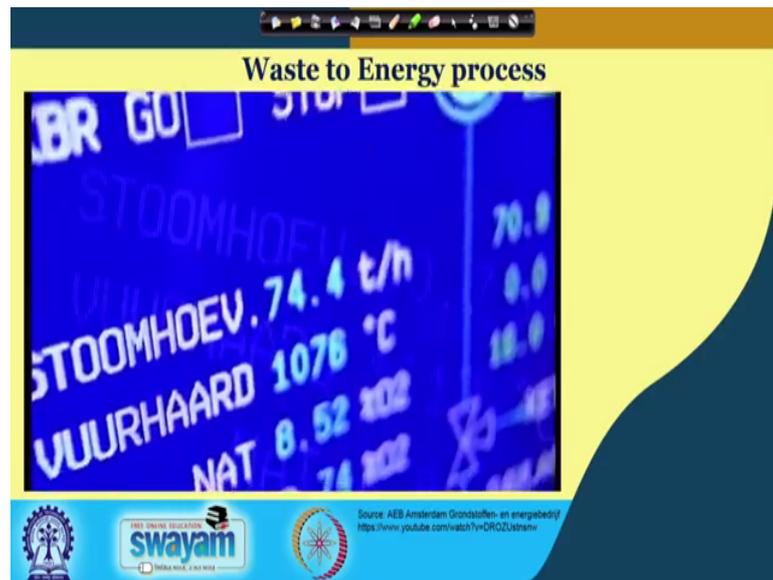
The waste is incinerated on grates.

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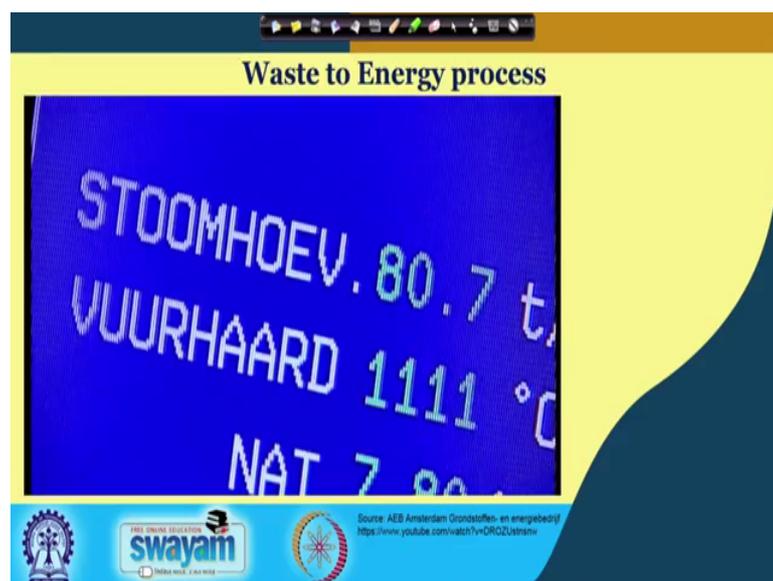


This is a continuous process 24 hours a day 7 days a week.

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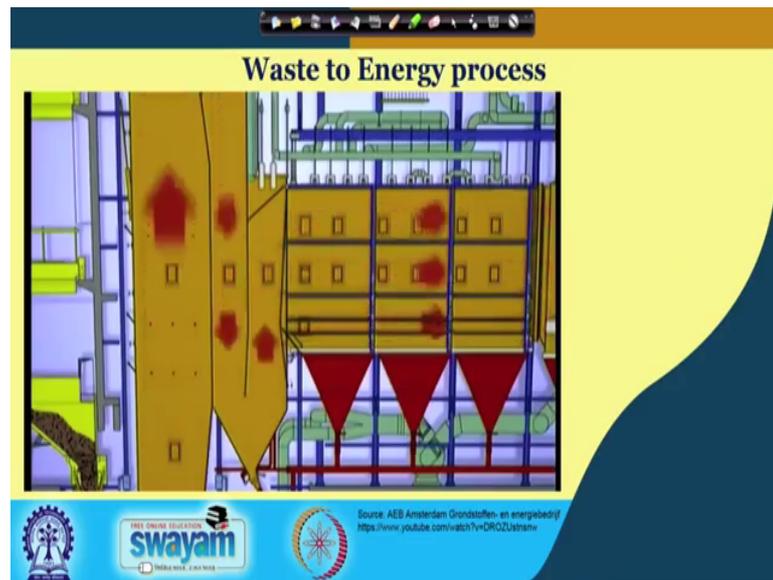


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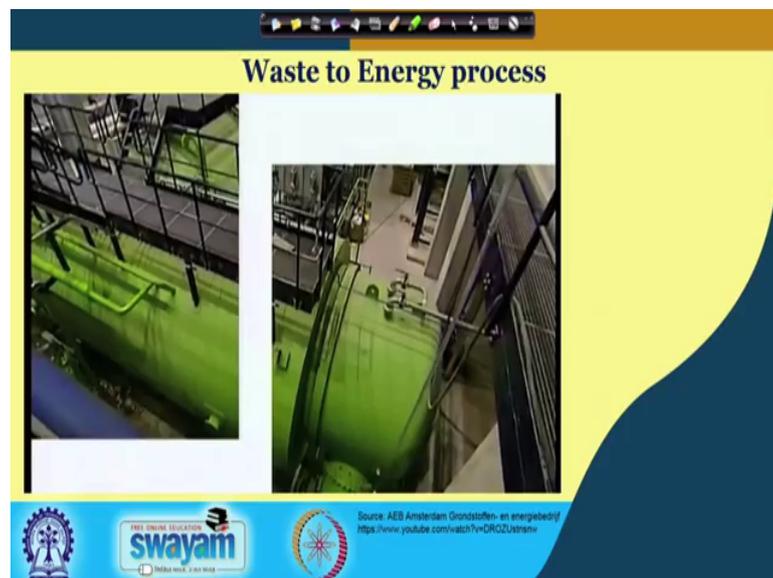
Temperatures range between 1000 and 1200 degrees celsius.

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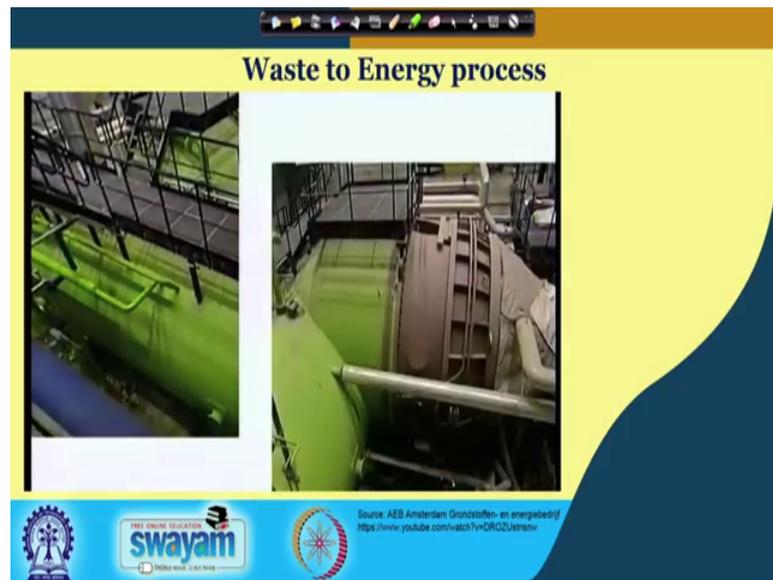
This heat is not wasted it turns water in the furnace walls into steam.

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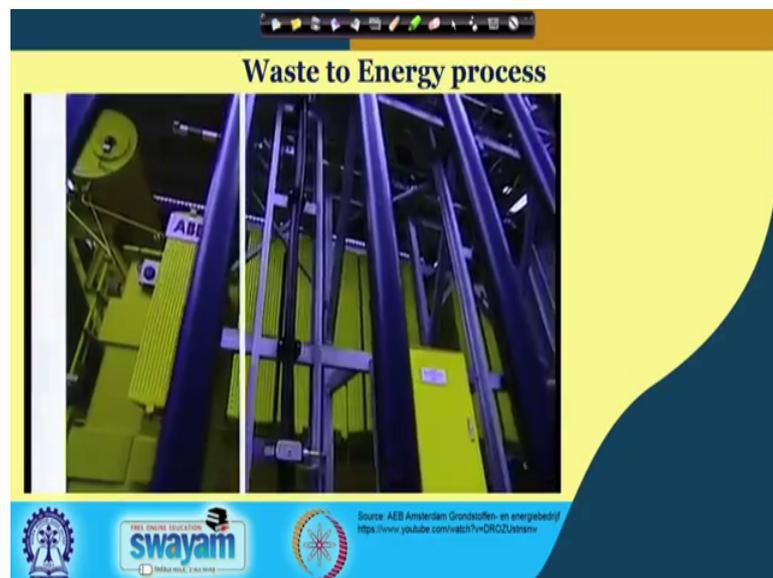
This steam passes through the three turbines at high pressure.

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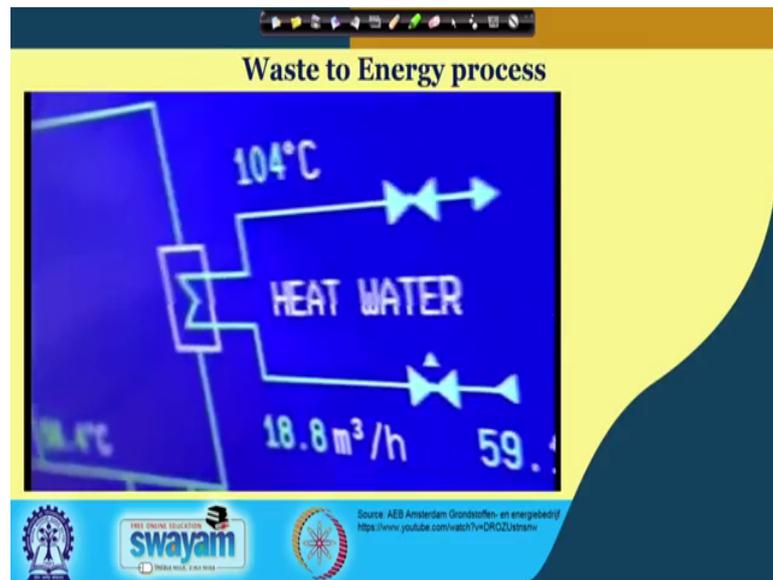
And the turbines drive a generator.

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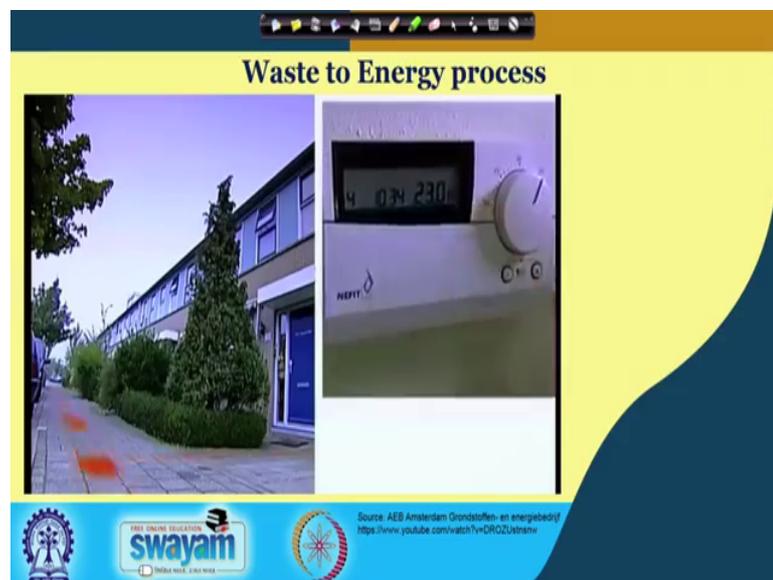
This generates enough electricity to power 161000 homes every year.

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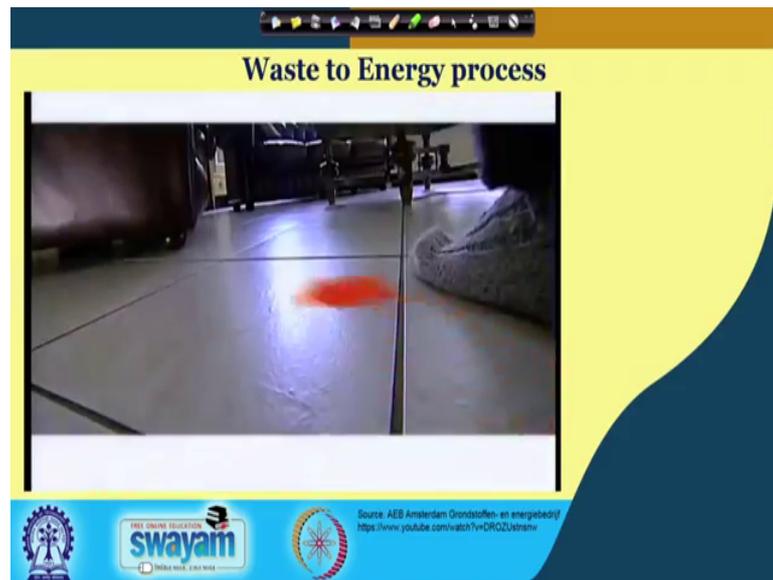
After the electricity has been generated the residual heat is used to produce heat for the city.

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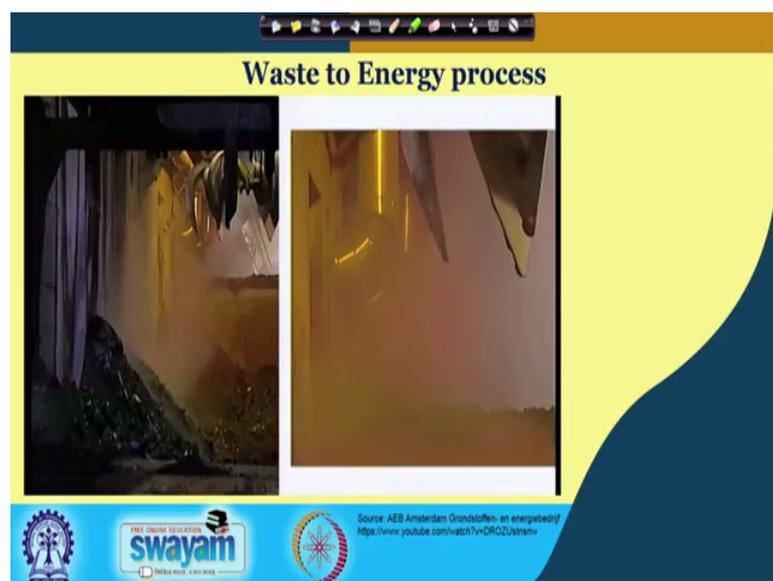


This is piped to the district heating system in Amsterdam and provides warmth for 15000 homes.

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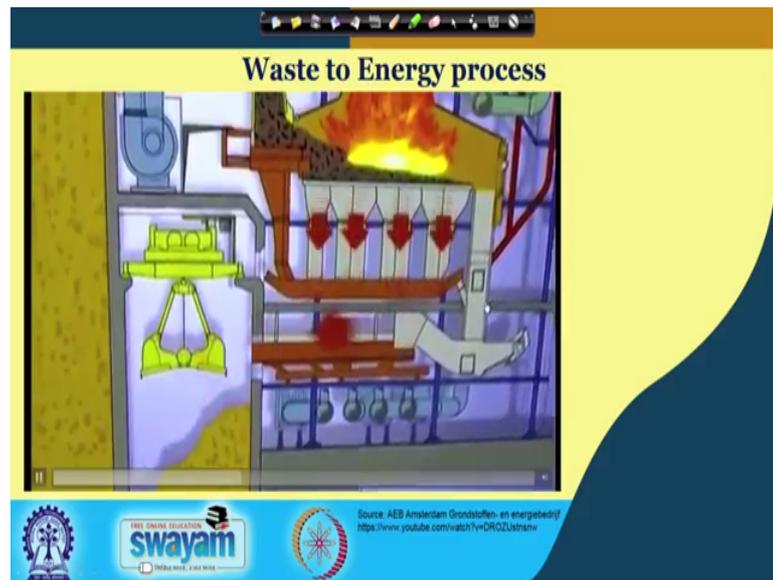


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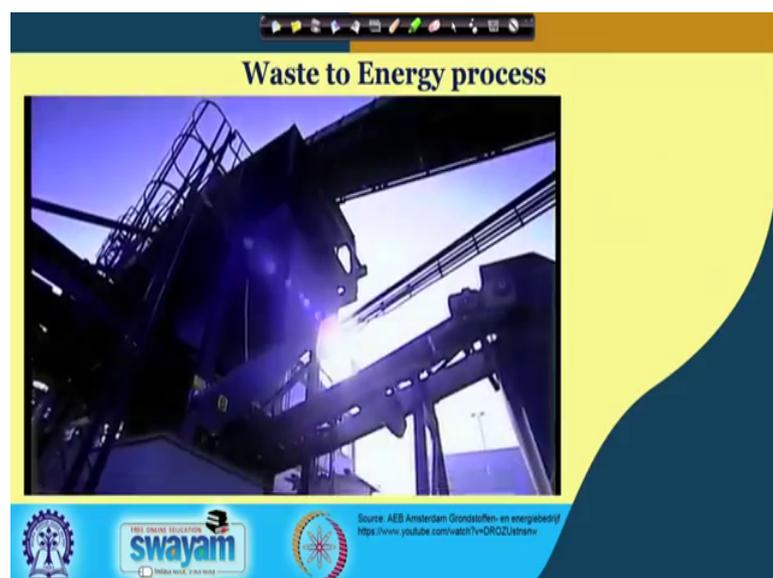


Part of the waste is combustible, this part which remains after incineration we call bottom ash.

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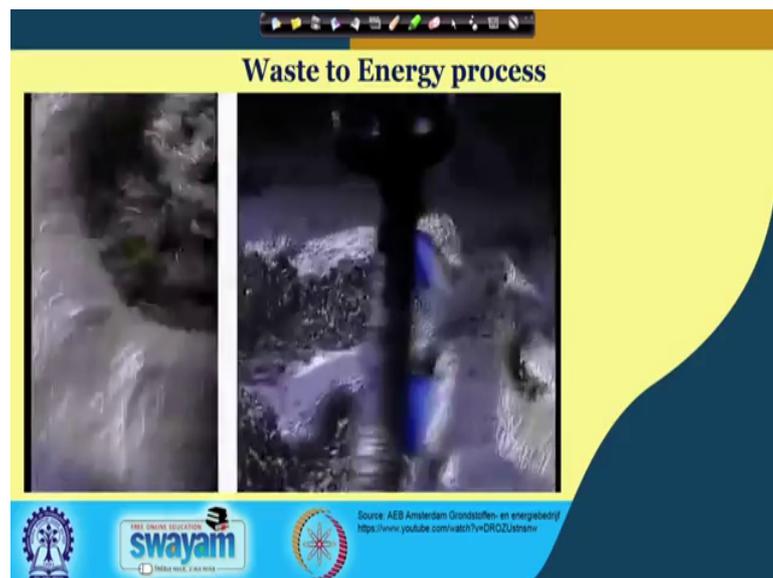
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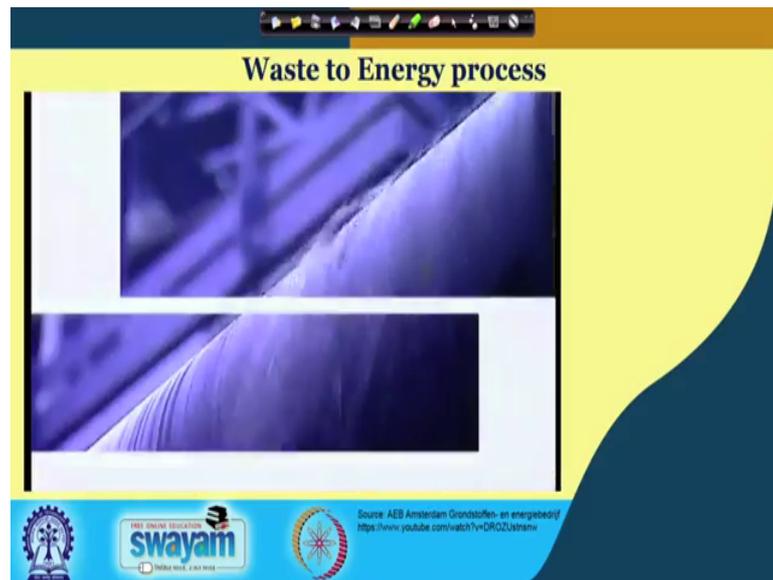


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Technology developed together with Delft University of Technology is used to wash and recover metals from the bottom ash.

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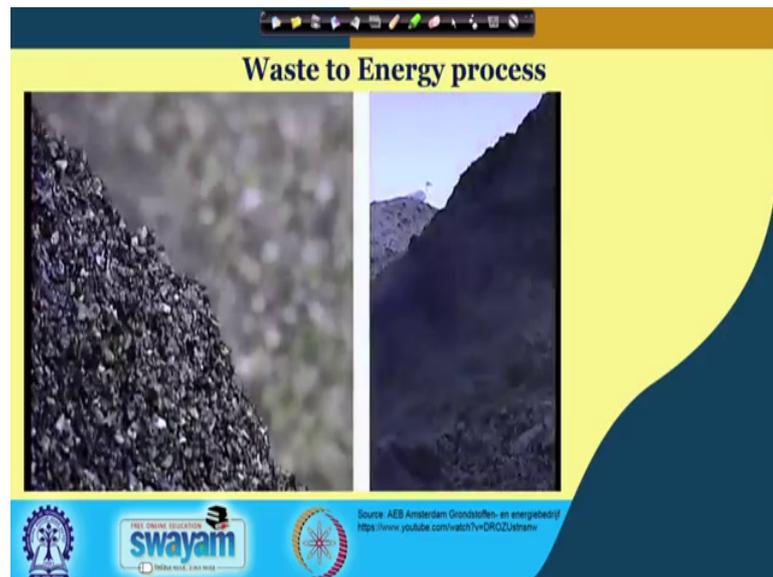


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Large amounts of iron and non-ferrous metals such as aluminium and copper are returned to the scrap metal trade for recycling.

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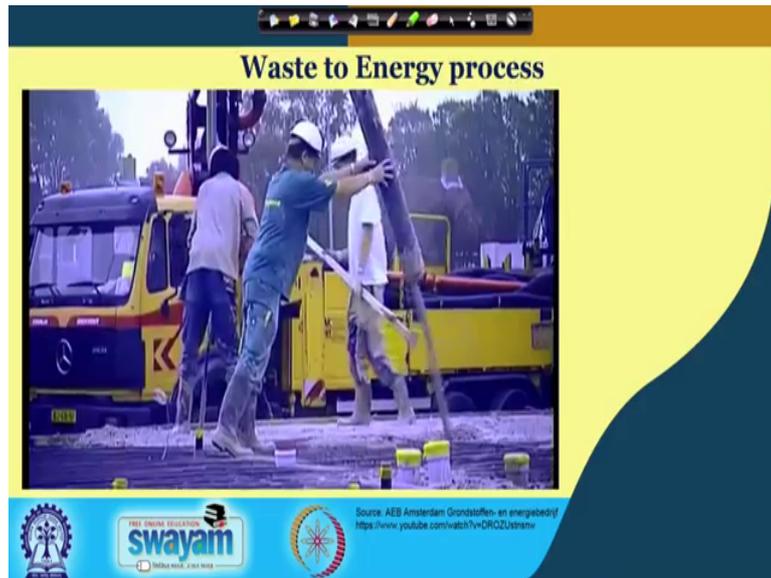


The rest is cleaned further until clean sand and a stony granular remain.

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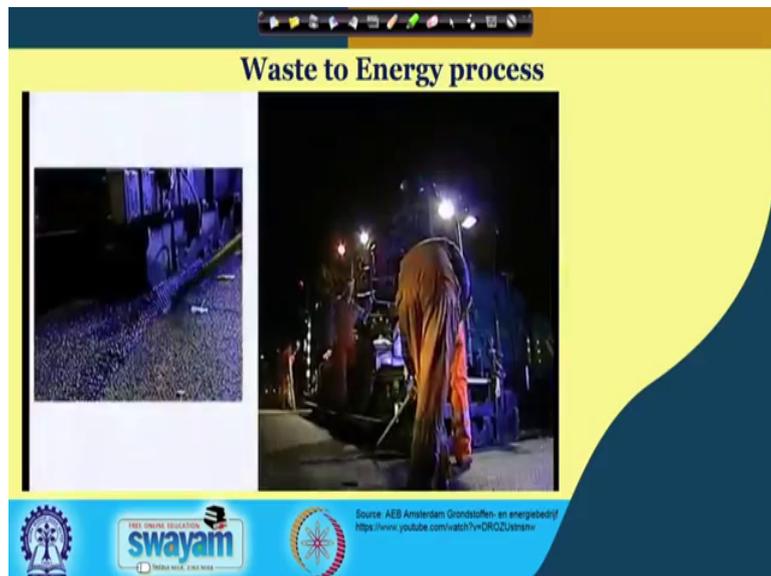


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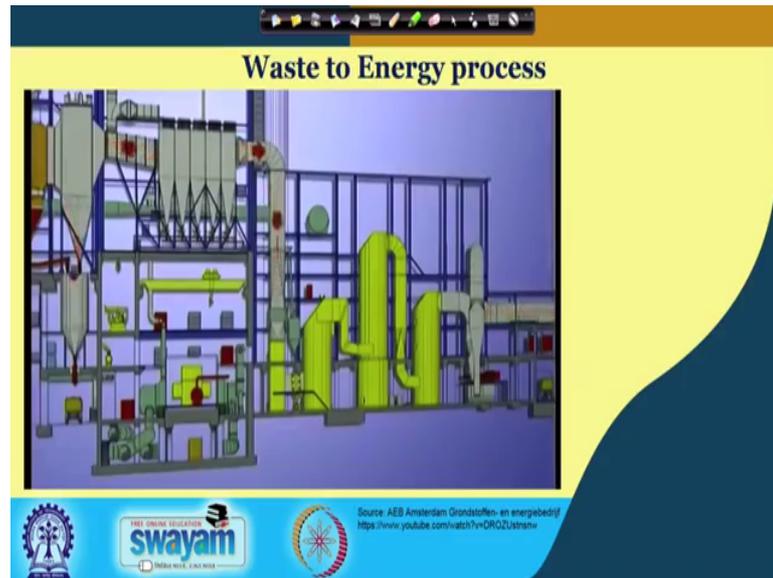


High quality building materials which are used: for example, in concrete and asphalt.

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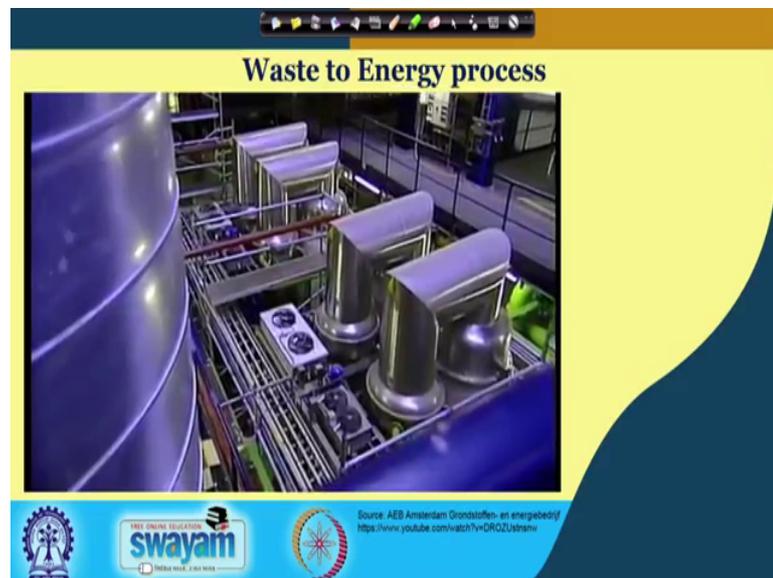


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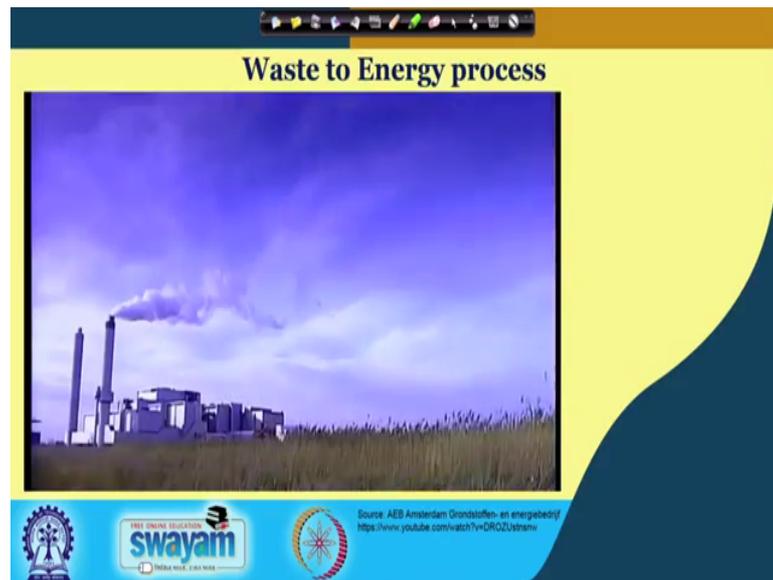


After the incineration process the flue gases are cleaned. This is the longest part of the whole production process.

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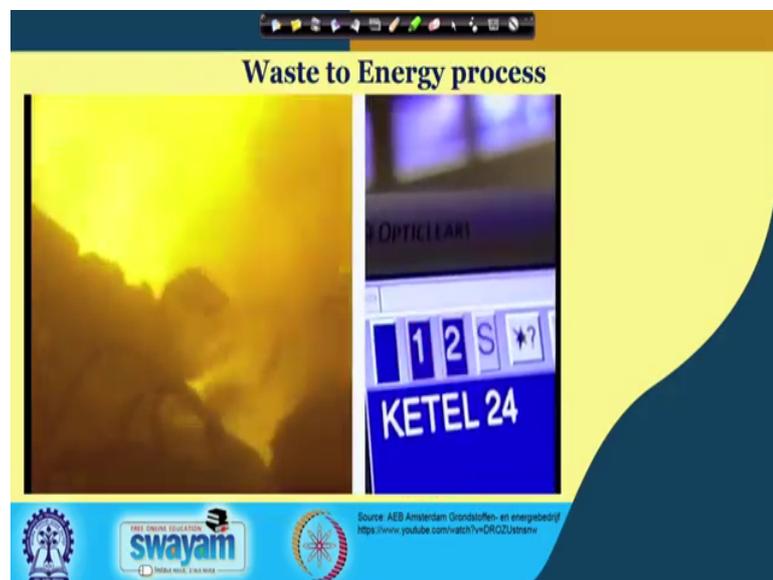


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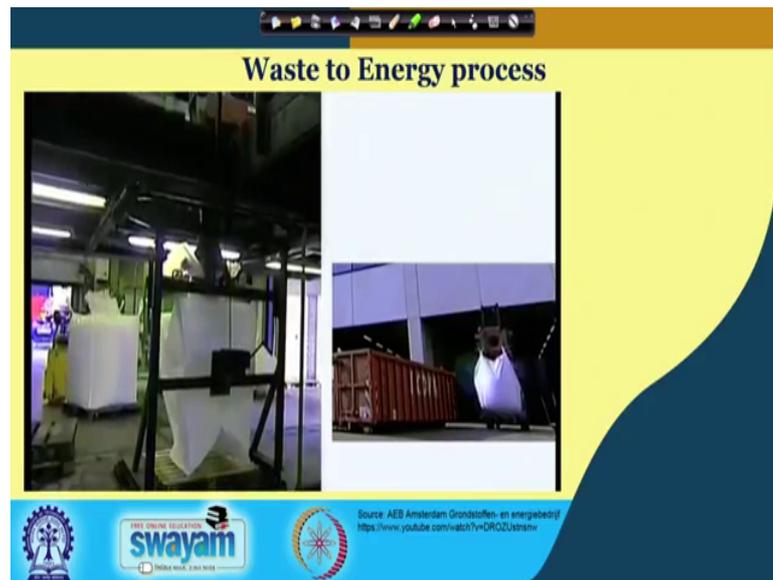
And all done to ensure that almost nothing is released from the chimney; there are strict government regulations.

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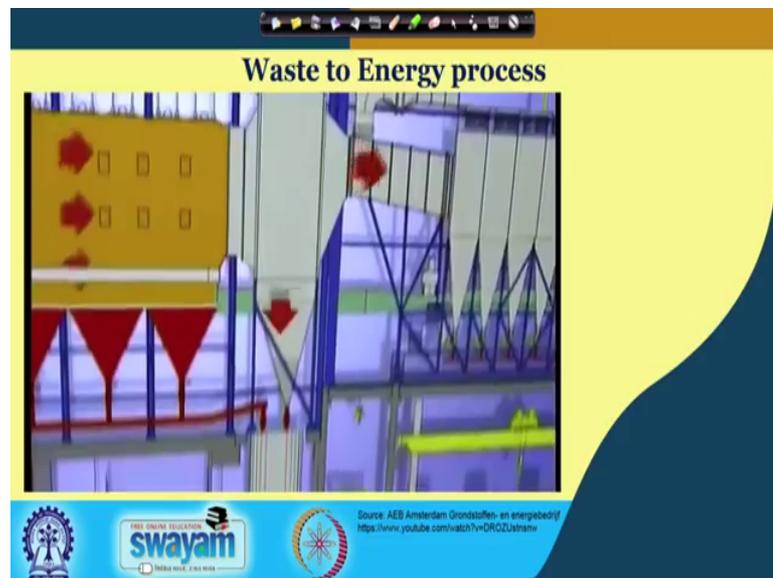
Emissions from the waste to energy plants remain well under the limits and we continue to work on improving this.

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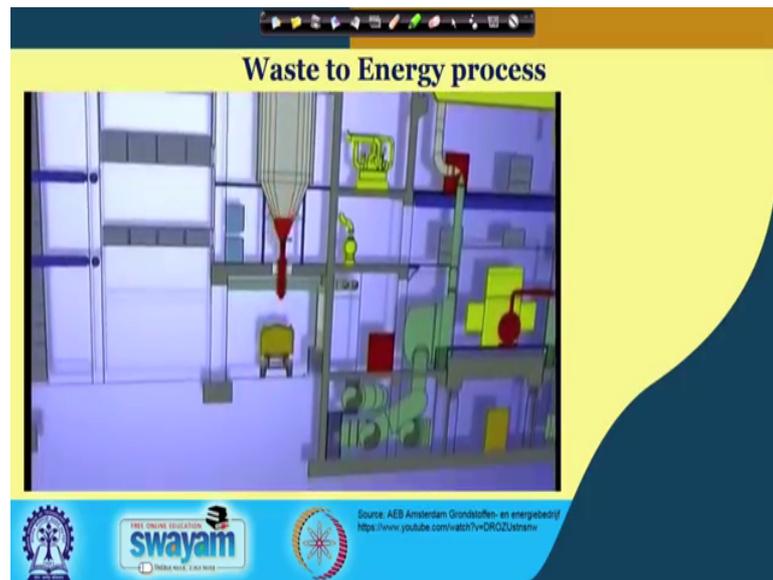


The flue gases are cleaned in a number of stages. We aim to recover useful products at each of these stages.

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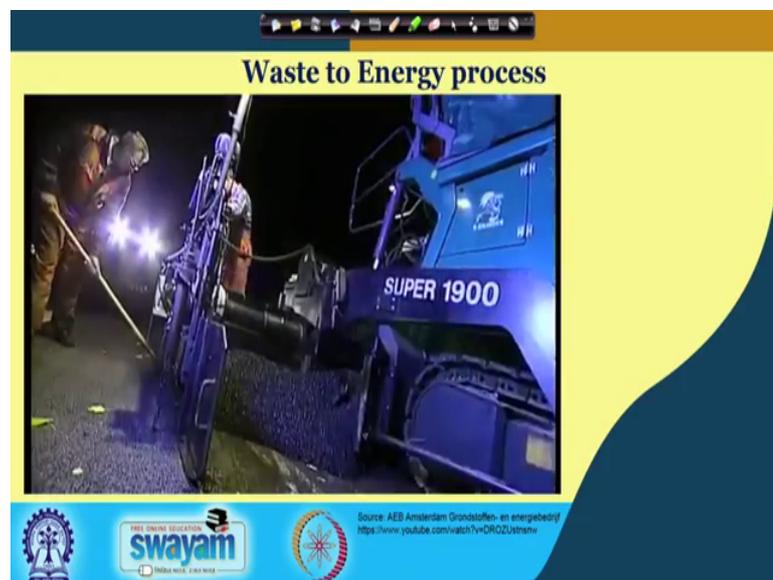


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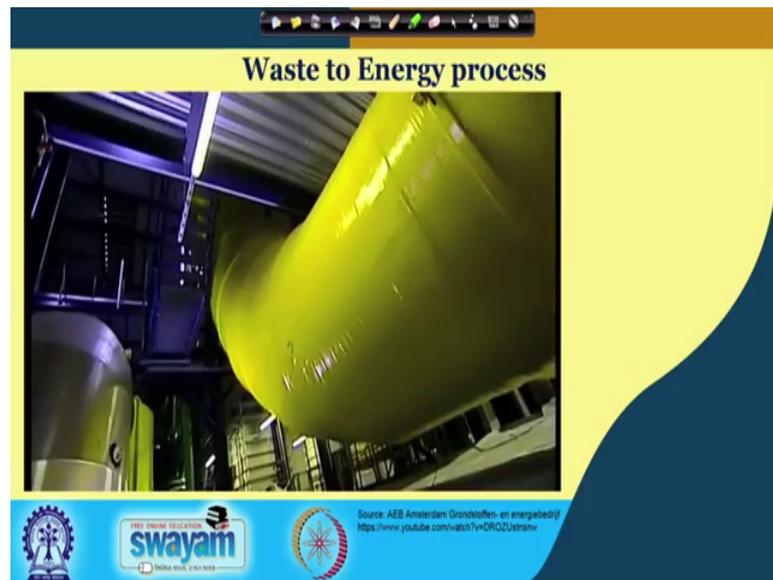
First of all flying particles are removed using an electrostatic filter placed behind the furnace exhaust duct.

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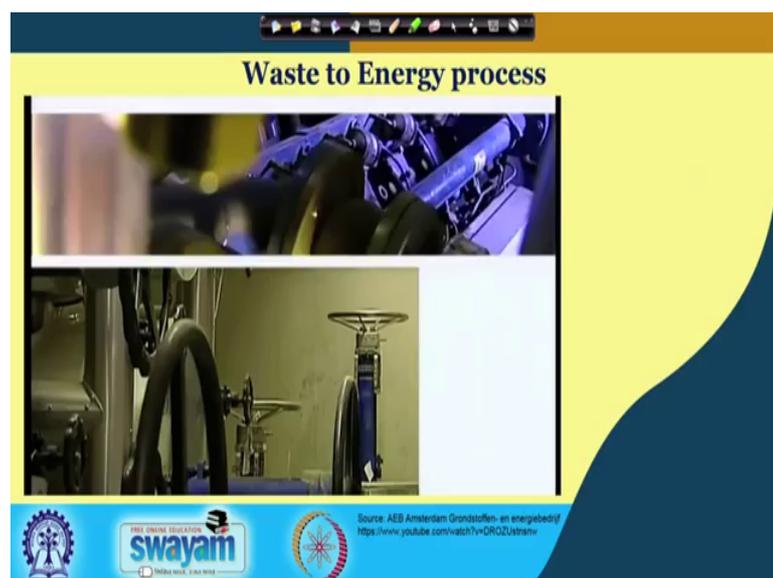


This fly ash is used as a filling material in asphalt.

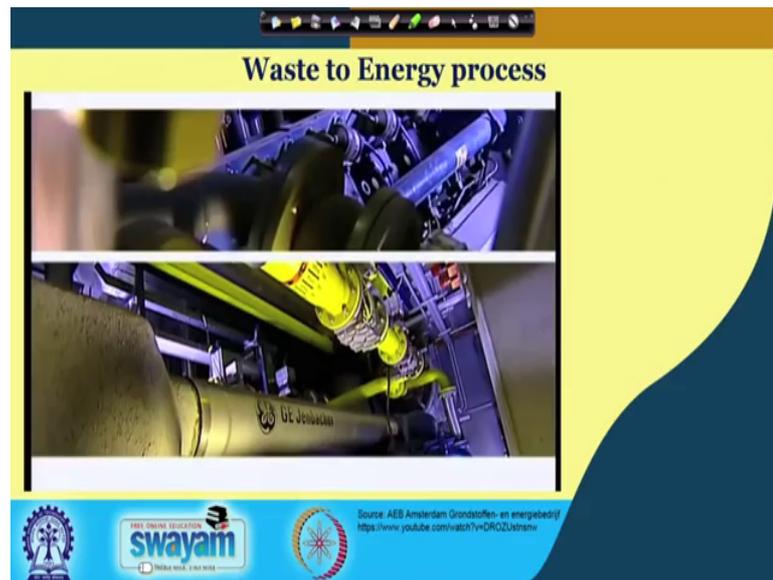
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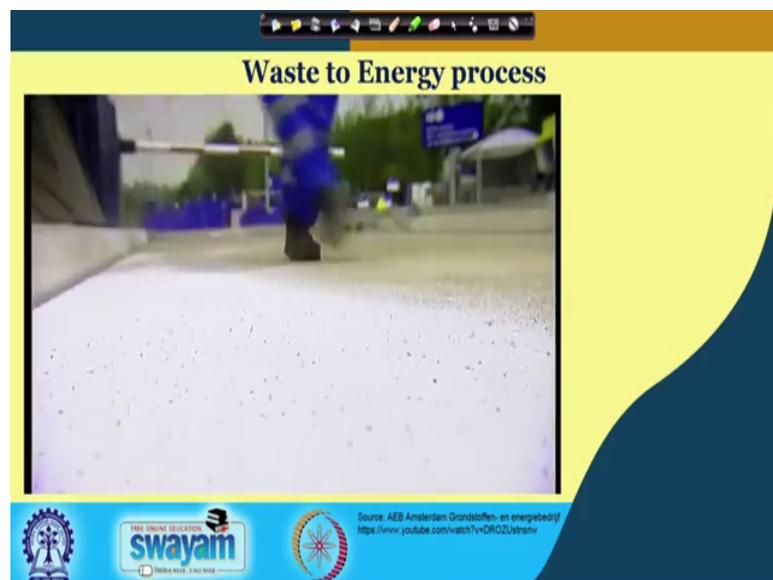


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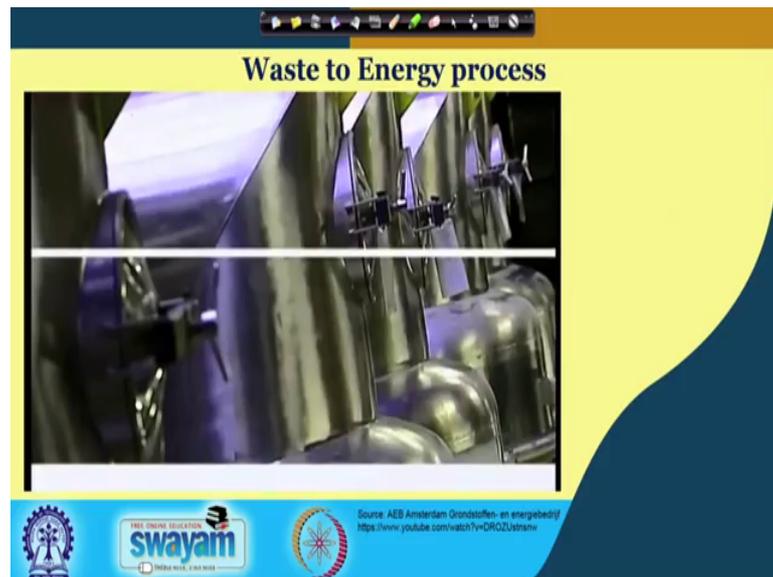
Dioxins, heavy metals and other environmentally harmful materials are then removed from the flue gases.

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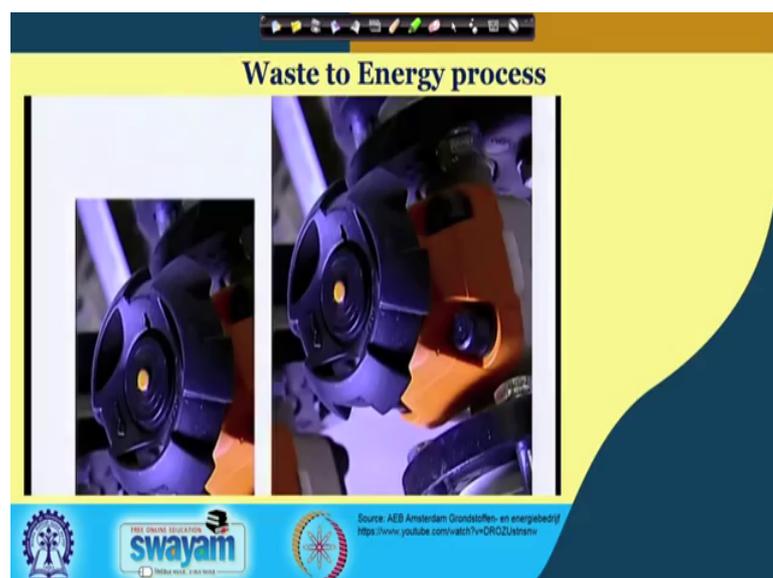


Plaster and salt for de-icing are recovered in the process and used in industry.

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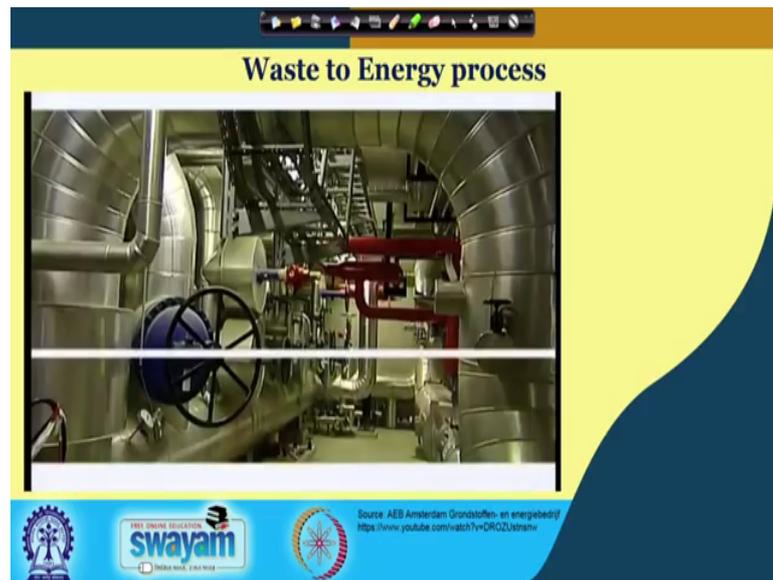


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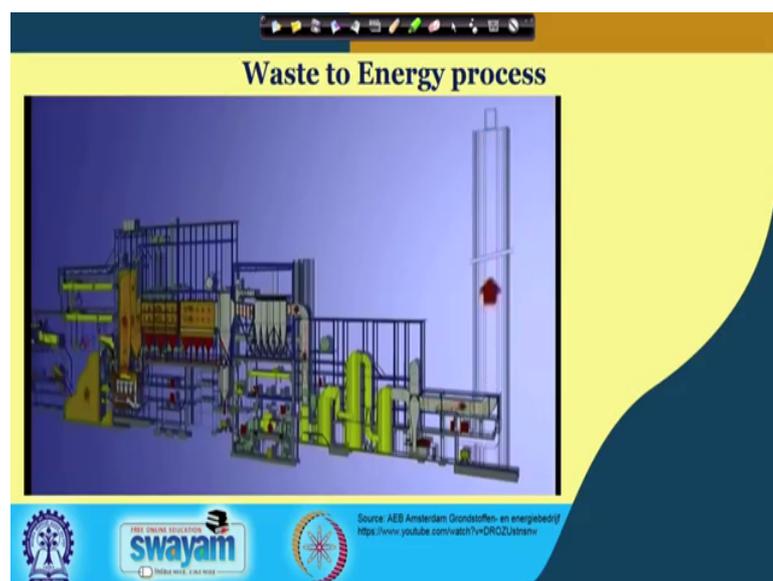


The water necessary for the process is recycled in a closed system.

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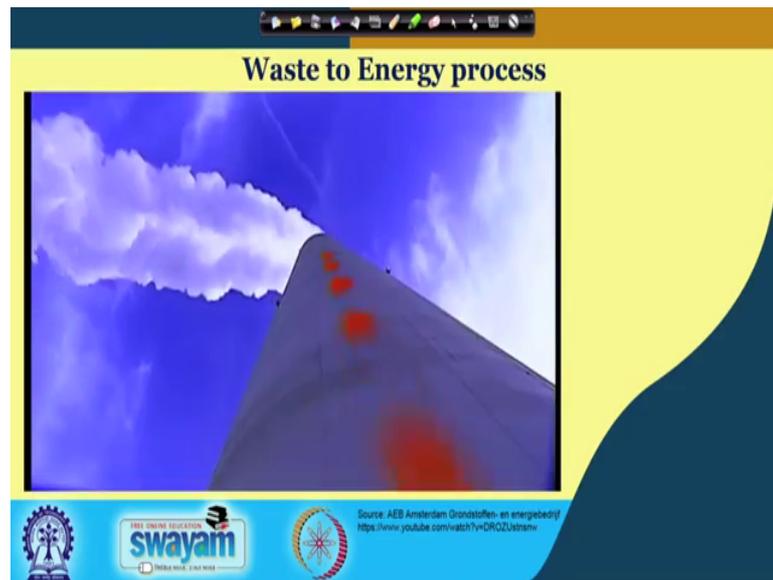


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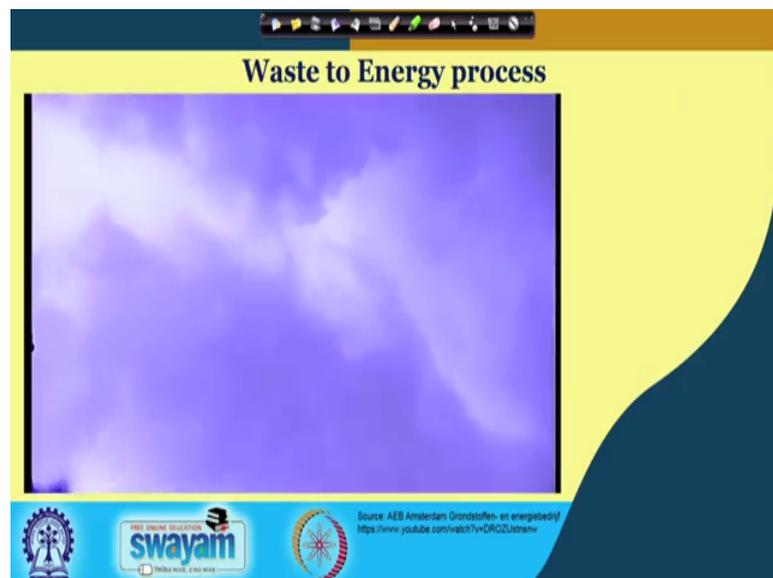
The installation therefore, produces no waste water.

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A sensor in the chimney constantly measures the quality of the discharged gases.

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The white plume of smoke is in fact, nothing more than basically pure steam.

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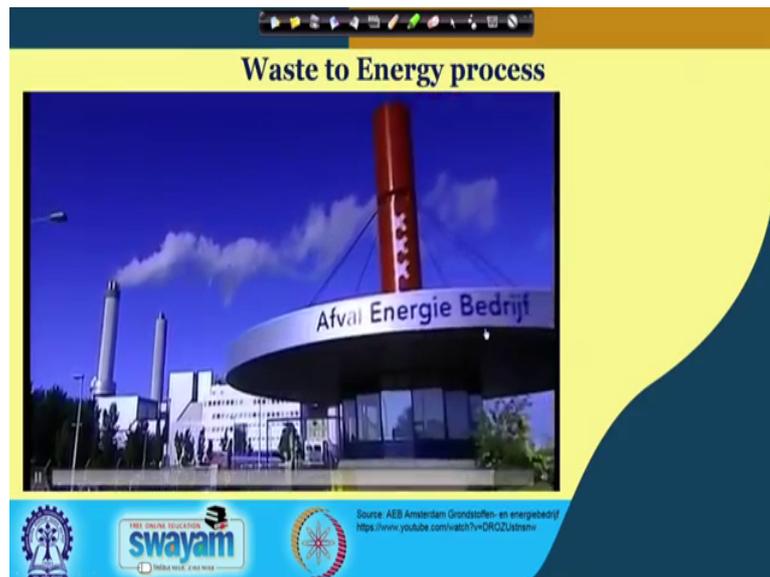
Only about 1 percent of everything that enters the waste to energy plant is actually left over.

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This is completely unusable and is disposed off safely.

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99 percent of the waste is converted into sustainable electricity, heat and useful building materials. You just saw the details, its it is one of the most comprehensive waste to energy plant in the world. So, that is the reason I wanted you to watch this one not the other, there are lot of other of waste to energy plants. There are three or four working in India right now; Jindal plant in Delhi, INFS plant and there are think there is a Ramky plant as well in Delhi. So, those three are working there are some other plants in pipeline in India as well. But, in terms of the whole comprehensive where as you saw in this video from the very beginning the waste that is coming in all the way to even management of those residual, the ash you saw that they were separating the ash into different fractions, different fractions is used for different application.

So, amount of waste that comes into that plant only 2 to 3 percent really ends up as waste. So, it is mostly towards like a 0 waste concept and these things takes time. It we like many times the students may come up with questions on discussion forum or during our live session saying that why cannot we do it in India. We can do it in India, we can have similar plants in India, we can do for municipal solid waste. But, thing is that our calorific value is very low, our waste calorific value is pretty low compared to European system. Our waste collection system is still is not proper because, a lot of everything gets mixed up together that is the reason why calorific value is low. We our waste is not covered, we get a lot of moisture coming into the waste then what type of food that we ate also has a lot of moisture.

So, overall we have moisture content is much higher that lays again lessens the calorific value. So, those though because of those kind of factors many of these plants in India struggle of to have a economical viability over a long term. So, being said that its still waste to energy is can be done in certain sectors in the country based on the calorific value numbers. And, but and to setting this whole system in place where, you have a like a gas collection and where you have the waste combustion. Then you have the heat recovery, energy production, residual ash recovery as well as using that ash for different application.

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**Advantages of incineration of plastics**

- High calorific value of the plastic waste produces high amount of energy.
- $\text{CO}_2$  and  $\text{CH}_4$  are produced by the thermal decomposition of the organic material and energy can be recuperated for further power/heat requirement.
- Generation of power, income and creation of jobs.
- Energy from waste projects provides a substitute for fossil fuel combustion because it is an exothermic process.
- Volume of the waste is reduced by incineration process
- In addition to burning, high-temperature environment will lead to the decomposition of toxic plastic components, such as benzene, etc.

The whole process is it is a complex process its and as this as the waste to energy industry evolves in country like India we will have those plants coming up maybe in 10 years 15 years from now, where you will have the entire things taken care of part of like a circular economy concept where things are being rather than having a linear economy. So, we will talk about that in our last week as well when we talk about circular economy concept.

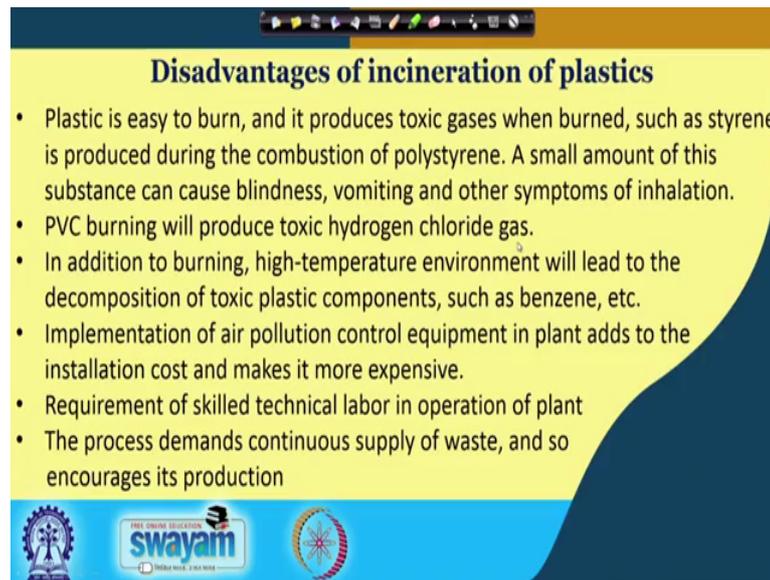
So, now what are the advantages of incineration of plastics? Its high calorific value plastics are essentially coming from crude, it is the petroleum based products. So, since it is a petroleum based product they have high calorific values. So, they do have a high calorific value. So, that helps in producing high amount of energy and when you do that this destruction you will have thermal decomposition of organic material. You have  $\text{CO}_2$

being produced, methane you will not see methane in a in the waste incineration plant. But, methane might be there from the bio plastics when we go for when we go for like a anaerobic digestion that is where.

So, methane here may confuse you. So, I just wanted to make sure you do not get confused with why methane has been put here for a waste to energy plant, for the incineration plant. It is not that much relevant for incineration, but when you go for waste to energy for using an anaerobic digestion especially for bio plastic which we will talk about in the next week where they will talk about this more. So, when you look at this bio plastic which is the biodegradable plastic when you go for anaerobic digestion there you will have methane showing up. In incineration you will have mostly CO<sub>2</sub> so, just wanted to make that clear so, that you do not get confused.

So, it is a methane is anaerobic digestion, CO<sub>2</sub> is mostly by thermal decomposition. So, when you have the thermal decomposition it is mostly CO<sub>2</sub> of the organic material and energy can be can be captured by further power and heat requirement. So, generation of power income and creation of jobs which are because of waste to energy, energy from waste projects provide a substitute for fossil fuel can be that said you can use it for a fossil fuel. Volume of waste is reduced, in addition to burning high temperature environment and led to the decomposition of toxic plastic components such as benzene. So, when you burn it at a high temperature you get rid of certain toxic material in the in terms of when you burn them.

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**Disadvantages of incineration of plastics**

- Plastic is easy to burn, and it produces toxic gases when burned, such as styrene is produced during the combustion of polystyrene. A small amount of this substance can cause blindness, vomiting and other symptoms of inhalation.
- PVC burning will produce toxic hydrogen chloride gas.
- In addition to burning, high-temperature environment will lead to the decomposition of toxic plastic components, such as benzene, etc.
- Implementation of air pollution control equipment in plant adds to the installation cost and makes it more expensive.
- Requirement of skilled technical labor in operation of plant
- The process demands continuous supply of waste, and so encourages its production

Logos at the bottom: Swamyam, and other educational institutions.

So, disadvantage of incineration plastic is easy to burn and it produces toxic gas such as a styrene produced during the combustion of polystyrene can cause styrene has a problem like a styrene gas can cause lot of impact. In terms impacts our vision, vomiting other symptoms of inhalation. PVC burning produces toxic hydrogen chloride gas, high temperature environment led to decomposition of toxic plastic components such as benzene. So, this is a that is actually in a that helps in reduction of benzene. Implementation of air pollution control equipment it adds to cost.

So, that is that is there the cost goes up, in terms of installation do you require a skilled the technical labour in operation of the plan, process demands continuous supply of waste and then so, encourages its production. So, essentially it if you that that is the common problem then common, I would not say problem the common criticism that we get for waste to energy plan is it actually its it is a negative to recycling. Because, most of the plastic which is we are talking about today and also other components, if you look at the paper textile and those they have good calorific value; plastic has pretty high calorific value.

So, if I am selling a waste to energy plan to deal with plastic waste along with my other municipal solid waste components that the recycling process of plastic is will may get a negative kind of push. People will try to send things to the incineration plant and not worry too much about recycling doing the recycling better that is a general argument

which you hear at many platforms in terms of plastic waste management. But, at the same time we also see that there are as you saw in the kind of one of the slide in the previous video that only 18 percent of the plastic is getting recycled. So, out of 100 percent that nine 82 percent is a still not being recycled.

So, they are ending up in landfill, they are ending up in the waterways. So, even if we go from 18 percent and improve our recycling rate to 36 percent, 40 percent, 50 percent rest 50 percent of the plastic needs to be managed too. So, it is so, in if you look at from a from a practical point of view, from an operational point of view a recycling and waste to energy both has its place and both system can be used. So, we talked about recycling in the first video and then we have talked about the waste sorry in this second video and we talked about this waste to energy in this present video.

And so, if you look at in isolation you kind of feel like or they are both competing with each other. So, if I if I my if my recycling is getting better my waste to energy will suffer that how it looks like, but in practical sense since our recycling is so, low even if our recycling improves it still we have lot of material out there which will be used in waste to energy plan. So, that is how the waste to energy can it still be a can be a good proposition for treating waste like plastic waste. The issue for waste to energy plant as we just discussed few minutes back in Indian context is since the calorific value is so, low it becomes difficult to manage this kind of plastic and this kind of waste in general which plastic does not come in isolation.

Plastic is there with you have your papers and other stuff and since we have the food waste and yard waste and street shipping is everything mixed together and it becomes problem in terms of a low calorific value. And, there those plants does not really walk very well from a economic sense all as operational point of view. So, with that let us just stop this discussion for this particular video right here. So, we talked about recycling, we talked about incineration, then next we will look at land filling and then we will also looked at use of plastic waste for different application like a road making and all that. So, thank you I hope you are enjoying the course.

Any feedback may you put it on the discussion forum, we will be happy if there is something we can do to help your learning in this course we will do that. There is a reading set of reading material, the PDF files other than these lecture slides for each

week and those are also on the web. So, do not forget for each from week 1 for until week 8 every week we have a set of a PDF 4 to 5, 6 files or around that number for each week. Sometimes you may have same file showing up in multiple weeks because, we are effort to them in multiple weeks and those are background materials kind of in on top of this slide.

So, I encourage you to read that and encourage you to refer that, if you want to have a greater depth knowledge of this particular course. And, you can ask questions from those if you do not understand on the discussion forum as well during the live session which we will schedule. You will have some you will have live session in this course as well so.

Thank you and see you in the next video.