Urban Services Planning
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Lecture 39
Waste to Energy Part IV

Welcome back. In Lecture 39, we will talk about the final part of waste to energy this is Part 4.

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The concepts that we cover in this particular lecture are two Experimental technologies pyrolysis and gasification, these are experimental technologies in India some application of them are already there in abroad countries, but in India we are still experimenting with these kinds of technologies, quick comparison of different waste to energy technologies.

Then, we will talk about currently operating waste to energy plants, then process of how to select a suitable technology and finally, we will do a case study on this selection process by which is assessment of energy recovery potential and analysis of environmental impacts of waste to energy options using lifecycle assessment.

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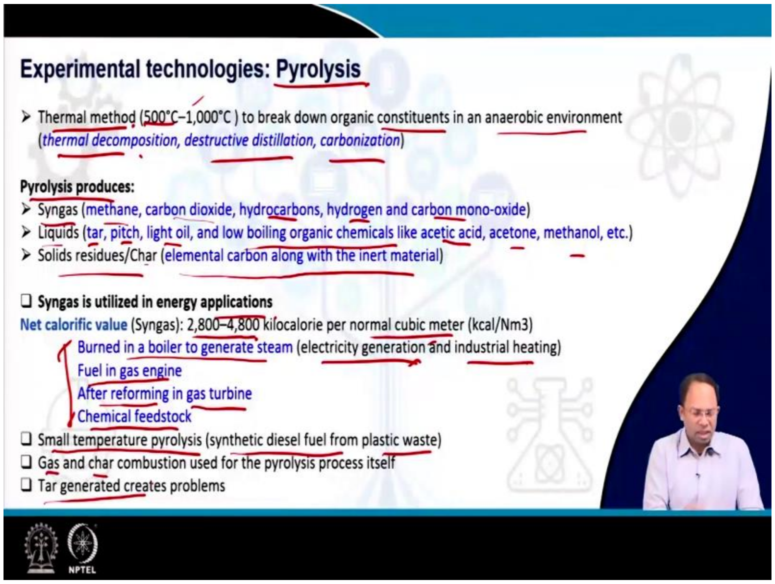

So, first coming to pyrolysis. This is the technology that we are talking about in developed countries there has been lot of some application of pyrolysis but again, these are experimental technologies, they are good for certain kinds of waste, but in general it is not found to be pyrolysis or, these are very, very sophisticated technologies requiring lot of investment and lot of, sophisticated manpower.

So, these are very, very difficult to implement and if the final product is of not that good quality, then there is no point of doing utilizing this kind of technologies, but in any way government of India is now exploring utilization of this technology. So, we will also learn about this. So, pyrolysis is also a thermal method or incineration method you can call where incineration happens at 500 to 1000 degrees centigrade to break down organic constituents in an anaerobic environment.

So, here the incineration happens or the burning happens in absence of air. So, but the temperature is much higher than the normal incineration process. So, we also call it thermal decomposition, this is also known as thermal decomposition, destructive distillation and carbonization.

So, the produce the products that come out of pyrolysis is something called Syngas, which includes methane, carbon dioxide hydrocarbons, hydrogen and carbon monoxide these are the primary constituents.

Some liquids also come out some usually the Syngas is condenses and then the liquids are formed. This includes tar, pitch, light oil and low boiling organic chemicals like acetic acid, acetone, methanol and so on. Finally, some solid residues also come out these are also known as Char, Char this is basically elemental carbon along with some inert materials.

Now, Syngas is the one we are very, very interested in it is similar to flue gas, it is used in energy applications that means that it is used in boiler operations and so on. The net calorific value of syngas is around 2800 to 4800 kilocalories per normal cubic meter**.** So, which is a bit higher than in the previous case and either the syngas could be burned in a boiler to generate steam.

So, this is an when you generate steam, you can use that for either industrial heating or you know, in the local heating or electricity generation directly via turbines and all. It could be used as a foil in gas engines, it after reforming the syngas, we can use it in gas turbines, then it could be also used as a chemical feedstock. So, these are the uses of syngas.

Now, in addition to that, we can also do small temperature pyrolysis using that we can generate synthetic diesel fuel, and particularly from plastic waste. But again, this has been explored in the Indian context as well. But the success rate is not that high. It is not that it is a difficult process. It is a complicated process. So it is difficult to implement in urban areas.

Then gas and char combustion used for the pyrolysis process itself. So we can use the gas as well as the char we can burn it again. And that it will can go that reduces the general this increases the temperature or improves the pyrolysis process. That tar that is generated sometimes it creates a lot of problems because it gets attached with the surfaces and all and you as you know that removing that is difficult.

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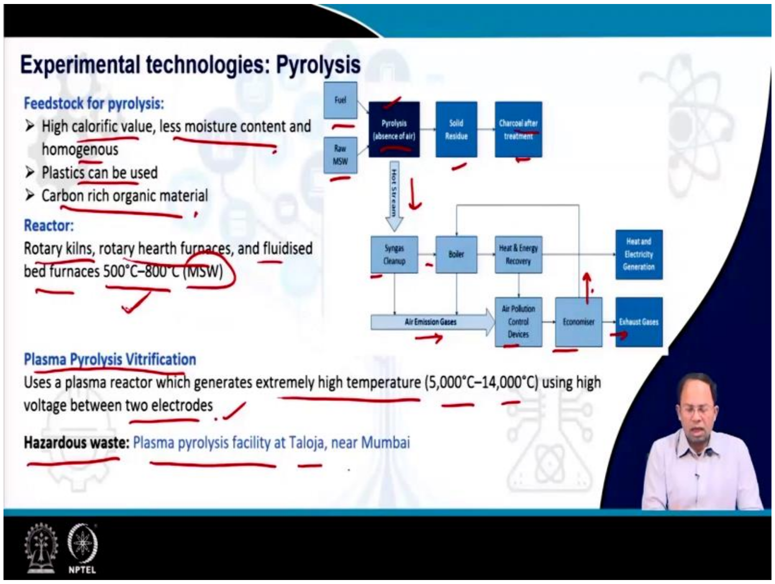

So, this is the pyrolysis process Fuel and Raw MSW is taken in pyrolysis is where incineration happens in absence of air solid residues comes out this after treatment this could form we can form charcoal from (())(5:22) karvy these becomes charcoal the hot stream that is the syngas this we have to clean up.

And then we can use it in a boiler to generate electricity and or we have the rest of the syngas needs to be taken we have to take this particular emission through air control a pollution control devices and from here we can reuse some of it through an economizer and the rest is exhausted out through stacks.

So, this is more or less same as the incineration process only thing is it happens in absence of air. So, feedstock for pyrolysis is high calorific value waste and of course, as you understand the quality of waste should be even higher in terms of calorific value compared to standard incineration less moisture content.

And it is the waste should be homogenous plastics can be used over here it is, we will suggest use a plastics carbon rich organic material is the final air product. The reactors different kinds of reactors are utilized rotary clean reactors, rotary health furnaces and fluidised bed surfaces, fluidised bed surfaces are where we use air and the movement of air as well. And here the temperature ranges around 500 to 800 degrees centigrade particularly for municipal solid waste we can go with this kind of incinerators this kind of furnaces 500 to 800.

Now, one new technology that is coming in these days is plasma pyrolysis vitrification where it uses a plasma reactor which generates extremely high temperature coming to around 5000 to 40,000 degrees centigrade and this is generated using very high voltage between two electrodes. And in this process more or less the entire the waste is destroyed all you the waste is converted to elemental particles and more or less all hazardous materials are destroyed.

So, this is this process is good for some sort of hazardous waste as well. So, for exactly that purpose for handling hazardous waste a plasma pyrolysis facility has been set up in Taloja near Mumbai.

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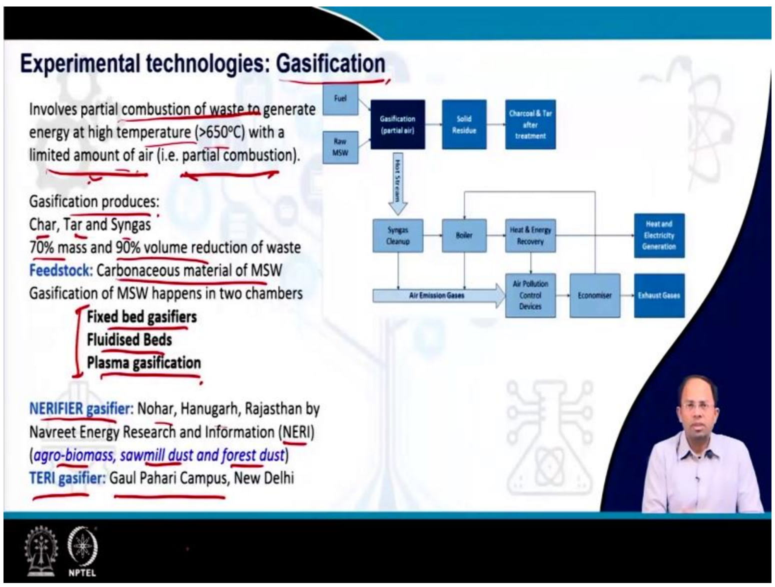

Next we come to gasification. So, this is the next experimental technology that is being experimented upon. This involves partial combustion of waste to generate energy at high temperature which is greater than 650 degrees centigrade, but with a limited amount of air. So, we are using air but a limited amount and because it is using limited air we are having only partial combustion.

Unlike standard incineration, we are having only partial combustion, where we are, the more or less the other processes is same, but we are using a lesser amount of air. This gasification process produces char tar and syngas similar to pyrolysis process more or less. There is 70 percent mass and 90 percent volume reduction of the waste. So, whatever waste goes in it is reduced to almost 90 percent.

The feedstock is carbonaceous material of municipal solid waste and gasification of MSW happens in two chambers. And it is the first chamber and the second chamber and usually we have fixed bed gasifiers, fluidised beds or plasma gasification systems. So, these are the different types of gasification system that are being worked upon.

So, one example of this is the Nerifier gasifier, which is at setup at Nohar, Hanugarh in Rajasthan, and it is set up by NERI. And this deals with agro biomass as well as sawmill dust and forest waste dust and so on. Whereas, another gasifier is set up by TERI at their Gaul Pahari campus. And these are two pilot projects which are also set up as demonstrators for this kind of systems.

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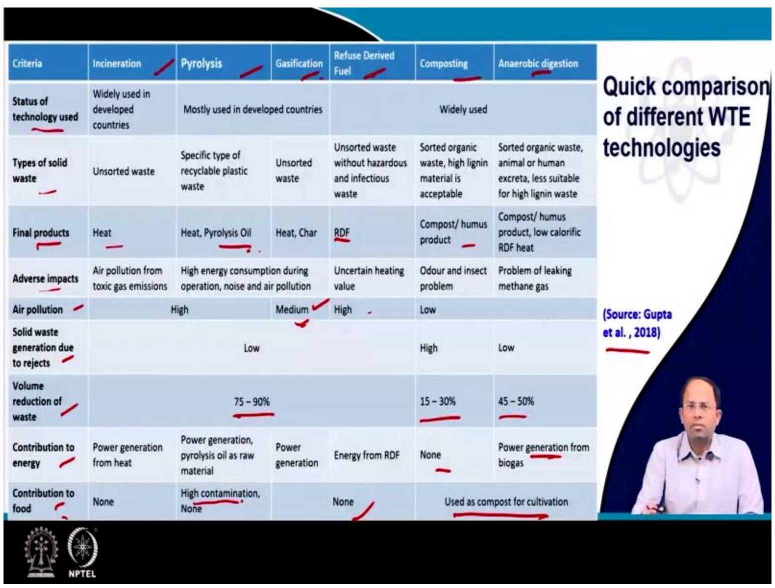

So, now that we have discussed about different ways to energy system including pyrolysis gasification, as well as incineration refuse derived fuel, anaerobic composting or bio methanation, so which one is best? How do we choose that right? So this chart given by Gupta et al this summarizes the different technologies in front of us that we can utilize incineration pyrolysis, gasification, refuse derived fuel composting, anaerobic so how do I choose?

So there are deep we can consider different characteristics like this the technology used type of solid waste that goes into that particular process, final products, adverse impacts, what are the bad impacts of these technologies air pollution, solid waste generation due to rejects how much amount of waste goes into the landfill site volume reduction of waste.

How much amount of volume reduction happens contribution to energy contribution to food production. So, of course, when we talk about anaerobic decomposition, as well as composting this contributes to food production because we are creating compost whereas, in case of other things like gasification refuse derived fuel, there is no contribution in those regards.

And same goes for incineration or pyrolysis whereas in pyrolysis, there is also chance of contamination, instead of there is no benefit but there is also chance of contamination. Now, in terms of heat production, there is no heat generated in composting, whereas in anaerobic digestion we have a biogas produced which generates, we can generate power using biogas.

And of course, the incineration processes or even refuse derived fuel processes, these are mostly for generation of power. So, volume reduction in burning we reduce in all different processes of burning or incineration we reduce waste content by 75 to 90 percent. Whereas, in composting we can only reduce to an extent of 30 percent whereas, in anaerobic digestion we can reduce it to around 50 percent.

Air pollution is very low in case of composting an anaerobic digestion whereas, it is high in case of refuse derived fuel can also in incineration, pyrolysis but in gasification the pollution is relatively lesser. So, that is why it is sometimes nowadays being preferred. The output products also we know we create compost and humors over here.

Whereas, over here it is primarily heat, but in pyrolysis along with heat there is pyrolysis oil and in RDF we definitely produce RDF which eventually could be converted into this heat as well as ash. So, what are the waste? Waste is required, so, that also may determine what setup process that we select eventually.

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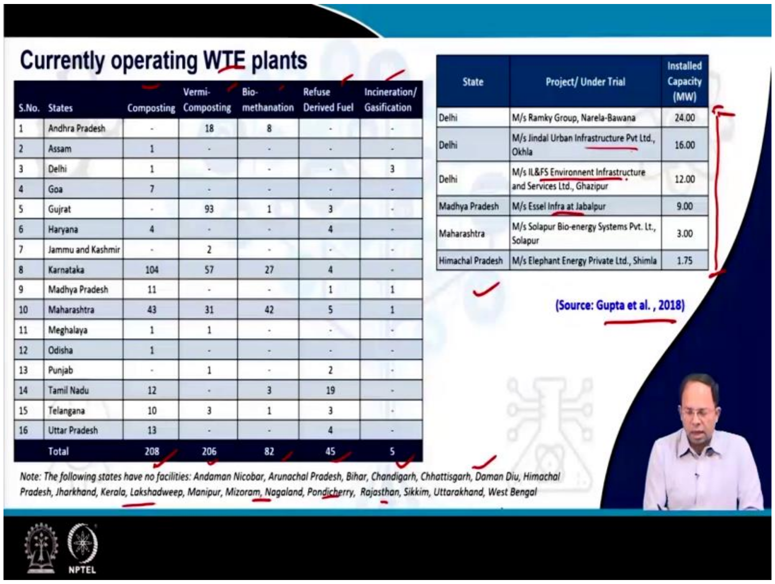

Now, coming to the different plants which are currently operating in India, the WTE plants all sorts of tons we have considered Composting, Vermi-Composting, Bio Methanation and Refuse Derived Fuel, Incineration or Gasification we see that there are around 5 of these plants operating and here you see the list of this 5 plants.

So, in Delhi, we have got Jindal Urban Infrastructure set up of plant, this ILFS has set up of plant in Madhya Pradesh, there is Essel Infra and you can see that total capacity of this standard plants which are all mostly medium electricity generating they have got medium capacity your electricity generation capacity.

Now, coming to the other product, other you know WTE plants around there are around 208 composting plants currently being operated in India, whereas there are 206 farming composting plants 82 Bio Methanation plants and 45 RDF plants which are currently operating. Now, these are some of the states where, as per 2018 reporting of data by Gupta et al.

These are the states which does not have any of these kinds of facilities, they do not have data on that, whereas, some of these of course, may have changed eventually, but at least during the time when this paper was written, this is the data that was available.

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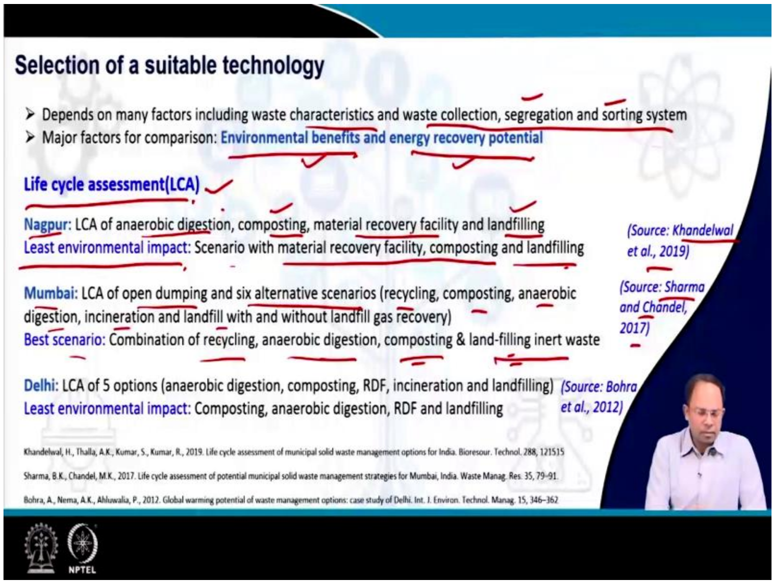

Now, how do I select the right technology for which waste to energy process or which process for that matter, we will use one treatment of solid waste? So, it depends on many factors of course, it depends on the waste characteristics and the waste collection segregation and sorting system that is adopted by the municipal body.

If I am having mixed waste, I am not doing any kind of sorting at all, then it is better we cannot have systems such as specialized systems which required sorted waste and all so, that we cannot do the entire sorting at the plant that is impossible we have to resort it somewhere else. So, it all depends on what sort of, intermediate collection and segregation technologies or processes you are adopting based on that we can determine what sort of technology we are going to adopt eventually.

But when we have come to a set of technologies for a particular city when we say that, these are the four options that we have got in front, then we have to compare between those to say which is the best option. So, in that case, environmental benefits of that particular of choice as well as energy recovery potential. These are the two primary aspects that needs to be considered.

Now whenever we are considering environmental benefits, or impacts or energy recovery potential, this has to be looked at very-very thoroughly, why because if I just say take look at the end product, that is the final product that is being produced, then the fact then it may show that the final product may be better is for one process.

But if I look into the overall lifecycle of the product that is starting from which are the intermediate processes, what sort of things could be done with those particular or what are the inputs to the these particular processes, what are the outputs to these processes, then we have to do a detailed analysis and that also starting for the entire process, starting from when what kind of raw materials.

How it was produced and eventually what happens, when we are finally disposing them into that atmosphere. So, for that we can do lifecycle assessment. So, we have learnt about lifecycle assessment in very broadly earlier and in the subsequent the next lecture, we will learn about lifecycle analysis in detail.

So, but lifecycle assessment helps us to do environmental analysis or impact analysis in a more detailed manner. Unlike standard environmental impact assessment or EIA, we can do lifecycle assessment which really takes us to the different processes to the different technologies and what are the impacts or the implications of use of those technologies.

So, three case studies Nagpur, these are actually these are studies not case studies, these are studies research studies, which are done by these authors. So, in case of Nagpur LCA has been utilized to evaluate anaerobic digestion, composting material recovery facility and landfill. So, how we are going to dispose waste?

So, these are the different options that are considered be different scenarios were created combining this different option because some amount of waste will go to landfill in any case. Material recovery facility will also result in some rejects, which will go to landfill composting will also have some rejects, which will go to landfills but which combination we are taking that is how we generate a scenario.

So, in this study, it was found the least environmental impact was in the scenario, which combined material recovery facility composting and land-filling for this particular city, considering this the kind of waste characteristics and composition of that particular area and so on. But a lifecycle assessment was done. In Mumbai, a similar study was done with using LCA of course, where open dumping was compared with six alternative scenarios involving recycling, composting, anaerobic digestion, incineration and landfill, landfill with and without landfill gas recovery.

So, we can just have a landfill or landfill with gas recovery that was considered. So here the best scenario was found to be combination of recycling, anaerobic digestion, composting and land-filling inert waste. So, this combination was found to be the best one, but you have to first create combinations, I will show you how it is done. But each of these combination means that some percentage of wasted recycled some percentage will go to anaerobic digestion and some percentage will go to composting and the rest remaining will go to land-filling.

So, once all these things are done, each of these processes has to be evaluated as per the input that goes into this particular process. What are the output coming out of those processes or environmental impacts of each of these processes and together, which overall scenario is better. So, you can study these papers as well if you are interested.

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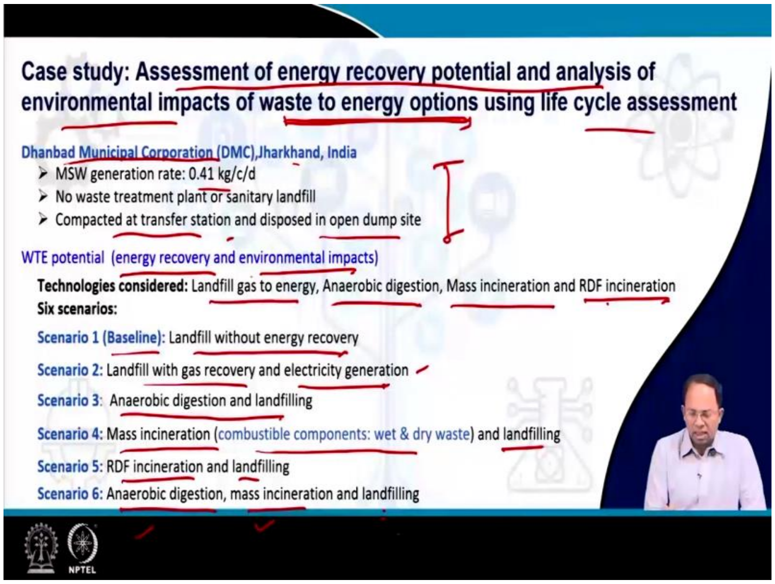

But today we will discuss one paper, which is a case study you can say, for assessment of energy recovery potential and analysis of environmental impacts of waste to energy options using lifecycle assessment. So, instead of looking at every option, we are only considering waste to energy options for a city and see which one is better.

So, this was this study was conducted for Dhanbad Municipal Corporation in Jharkhand, India and the waste generation rate over here is around 0.41 kilograms per capita per day. And right now, there is no waste treatment plant or sanitary landfill in this particular area. So, waste is taken, collected, compacted, taken to a transfer station and eventually disposed to a open landfill site or open dump site. So, that is the situation now.

So, now, suppose you want to propose some new technology or treatment process or disposal process for this particular city, how will you go about it? So, that is where different technologies needs to be considered. And we need two different scenarios for this particular combination of technologies.

So, we have to, so, in this particular study, not the overall cost, there will be different things that we can look at cost of this particular combination of technologies that we are proposing feasibility and land area availability, lots of analysis could be done, but over in this particular study, they have only done energy recovery and environmental impact analysis.

So, it is as per the goal of the study, they are limited to energy recovery and environmental impact assessment, but they could have done assessment of other things as well. So, the technologies considered our landfill gas to energy. This is one form of energy recovery, anaerobic digestion or biomethanation, mass incineration that is plain incineration and RDF incineration that is producing RDF and then insinuating there.

Six scenarios were generated the first scenario is the baseline scenario or the current scenario you can say, this is landfill without energy recovery, that means our standard open dump site. The second scenario is landfill with gas recovery and electricity generation that is the CH_4 within that would be collected would be utilized for electricity generation, not the entire CH_4 is collected, but maybe 70 percent of it is collected and that is used for producing electricity.

Anaerobic digestion and land-filling that means the organic waste goes for anaerobic digestion and dry waste goes for land-filling. Mass incineration that is combustible components of wet and dry waste both goes for incineration as well as land-filling, then RDF, incineration and land-filling.

That means some amount of waste is converted into RDF the rest goes into the land-filling. Anaerobic digestion, mass incineration and land-filling. That means both organic waste is an aerobically digested like biomethanation, mass incineration that means we have a incineration plant as well as the remaining waste goes into the landfill site.

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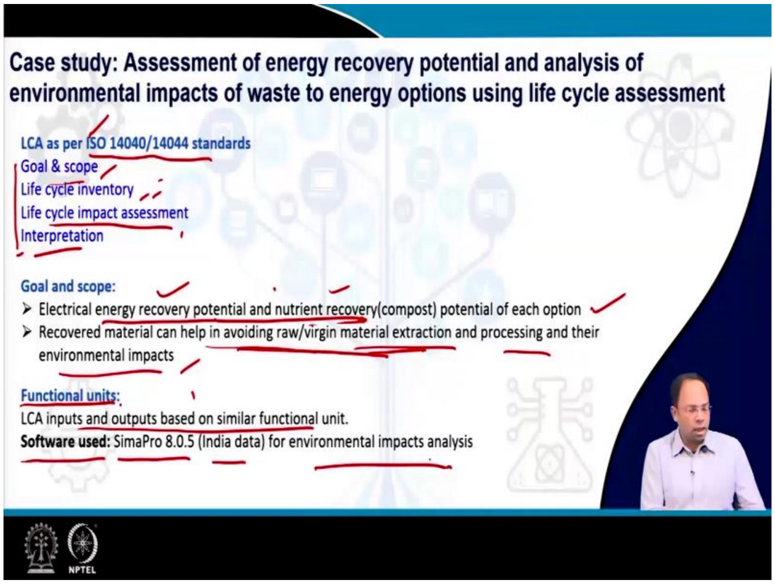

So, this study has been conducted using lifecycle assessment and for that framework is followed which is the ISO 14040 14040 framework or standard. So, we will learn about this in detail in the next lecture. So, how what are these frameworks, the frameworks are basically structure of the analysis which are given by this standards organization.

So that we everybody adheres to the framework follows the same steps, so that the resulting analysis is uniform. So LCA has to be done as for certain frameworks. Now LCA has got different steps, the four steps are goal and scope, defining the role and scope that means what I am dealing with, what analysis I am going to do for whom I am going to do it, and so on.

And also what would be the things that I am going to analyze what would be my system boundaries, that is what I should consider what I should not consider, which processes should I consider? Should I consider the, the recyclable materials, the materials which are coming out of compost, then it is again applied to the field? Should I go into that as well?

Or should I limit myself to production of compost? Or we should look into the energy processes in detail. And or we should stop at just how much energy is produced. So we have to create the system boundaries, or we have to define our goals and scope. So that is the first thing then comes the lifecycle inventory, which is basically we assess what sort of input goes into each of these processes, and what sort of outputs that comes out of these processes.

And once output comes out we can do a lifecycle impact assessment that what impacts is create on the environment impacts are like GHG product emission, greenhouse gas emission, it could be acidification, eutrophication, it could be human toxicity and so on. And finally, interpretation is to understand the results and to say which is probe which is better, which is not and to understand the results in this particular context.

So, in this study goal and scope is defined as electrical energy recovery potential and nutrient recovery. So, this is the only thing that we are looking into that how much energy could be required and how much compost could be produced and the recovered material can help in avoiding raw virgin material extraction and processing and their environmental impacts.

So, it is not only that we are producing some material, but also this has got some benefits, but at the same point of time, this to produce this kind of a, or to run these kind of processes like composting or, incineration, we request some amount of energy some amount of raw materials. So, these are inputs. Similarly, when we add result, we are producing something; we are also not utilizing raw material or fossil fuel.

So, if we are generating fuel, like RDF or we are generic burning waste, we are creating heat and electricity. So, that means, and this could be used for electricity production, but that means, we are avoiding production of electricity by normal process like using coal or so, on. So, there are a lot of benefits from that.

So, this is called the things that the avoiding raw virgin material extraction or processes. So, this has to be defined, then functional units are the different functions and processes that we are going to consider. So, LCA inputs and outputs based on similar functional units. So, whatever functions we are considering for each process.

Those has to be similar and you have to determine what are the inputs and outputs to this process and to do this kind of input and output what input results in which process which input is used in which process, which process leads to which environmental impact. So, this there is a huge list of all this, these are maintained in form of libraries. And for that we use software's which can which have this information in built into them, and they can help us in doing this impact assessment analysis.

So, one of the software's is SimaPro 8.05 that has been utilized in this particular study, and this has got lots of data from India and particularly in regards to environmental impacts of particular inputs, and that is being utilized in this particular study.

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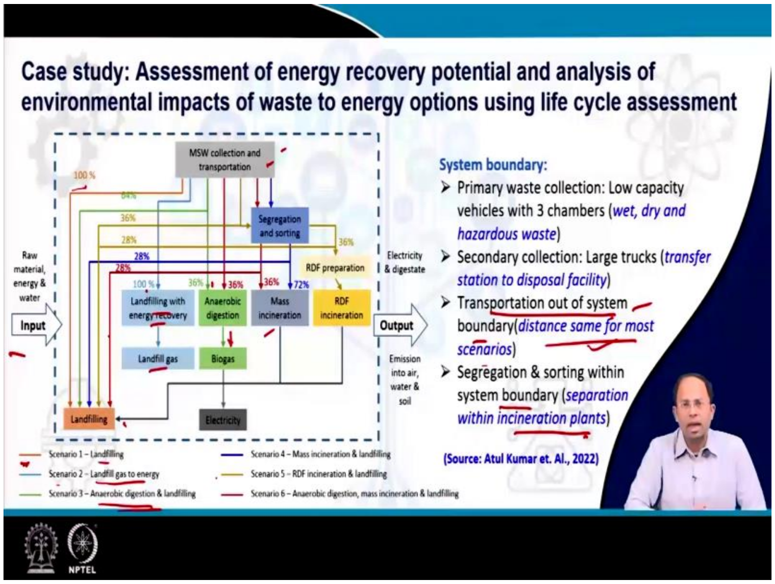

So, that system boundary is defined in such a way where transportation is kept out of the boundary that means, whenever this kind of process happened for suppose I am collecting and transporting the waste, but if I based on which scenario I choose, like scenario 1, which is land-filling, scenario 2 which is land-filling gas to energy, scenario 3 is anaerobic digestion and land-filling, we have to transport the waste to different facilities that will generate a lot of inert waste or rejects, which has to be again transported to the landfill.

So, transportation is a big deal that will transfer a lot of energy spent in transportation, but in this particular study, it is assumed that the distance of all these facilities and all is very, it is all nearby. So, we can ignore the transportation cost, but in real life, definitely this will play a large role.

So, in my system boundary of this particular study, I am saying transportation cost is not considered what we are considering is segregation and sorting within the different incineration plant that means segregation and sorting is not done separately outside, but inside the plant, we are assuming that segregation and sorting facilities are done and that would be taken care of. So, over here you can see the inputs and outputs and MSW collection transportation is over here.

So, in the scenario one which is land-filling, in this particular color, you can see 100 percent of the waste goes into the landfill site. Whereas, in scenario 2, which is in blue color, this also goes into the landfill site, but land-filling with energy recovery is there and landfill gases produced. Whereas, so, 100 percent goes into this one, in case of scenario 3, which is anaerobic digestion and land-filling.

You can see that 36 percent comes from anaerobic digestion the rest 36 percent goes into the landfill site. So, from here also the biogas is being produced and finally, electricity generation. So, similarly, in case of scenario number 4, where, like over here you can see some value some amount is coming for mass incineration.

And then some amount of it is going back to the landfill after mass incineration. Some amount is directly going into the landfill. So what volume goes into the landfill or mass integration? Based on each scenario, we are defining this percentage and that determines my system boundary. That is how I am designing the overall system. What are the limits I am creating based on which I will do the analysis.

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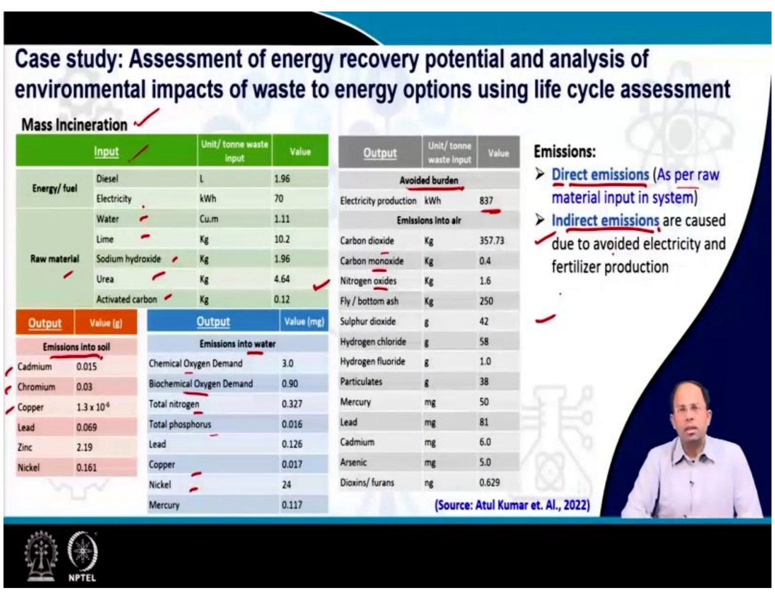

The next step in the process is to determine inputs and outputs of each process. So over here, the processes are incineration, the mass incineration, the process is composting, the process are anaerobic decomposition and so on. So these are individual processes.

So, inputs and outputs are considered from these processes and direct emissions as well as indirect emissions both are considered. Direct emissions, is as per the raw material which are inputted into the system there would be some emissions coming out. Whereas for indirect emissions, are raw materials which we are not using or avoiding the virgin materials we are producing, so those materials would have resulted in certain emissions, so we have to also keep track of that.

So, that means because I am using compost or because you are using RDF, I am not generating electricity or from coal. So, but if I would have generated electricity from coal, then probably there would be some emissions, some impacts and all which also needs to be considered when we are analyzing the overall process.

So this tables show the mass in support mass incarceration, similarly, this is done for all the different technologies, incineration, anaerobic digestion, landfill with gas recovery and so on. For each of these we are determined what are the inputs over here you can see the energy and the raw material inputs, diesel and electricity are the inputs for mass incineration also water, lime, sodium hydroxide, Urea, activated carbon, these are the material inputs, these are some of the reagents that we use and all.

So what is their value quantity and all? Similarly, what are the outputs emissions which happened to the soil domain, which is like cadmium, chromium, copper, all the heavy metals that get mixed in the surrounding soil emission seem to water that COD chemical oxygen demand BOD, biochemical oxygen demand total nitrogen phosphorus, late copper nickel that gets mixed into this water and finally, the overall avoided burden that is for this indirect emission, what we are not producing.

So electricity production value carbon dioxide, carbon monoxide nitrogen, these are not produced because we are doing this. So, that is why we have to look into both direct as well as indirect emission and this is done for all the different processes. And then we can understand for each of these processes, what are based on the inputs, what would be the outputs that are coming out as well as what are the avoided outputs that are generated.

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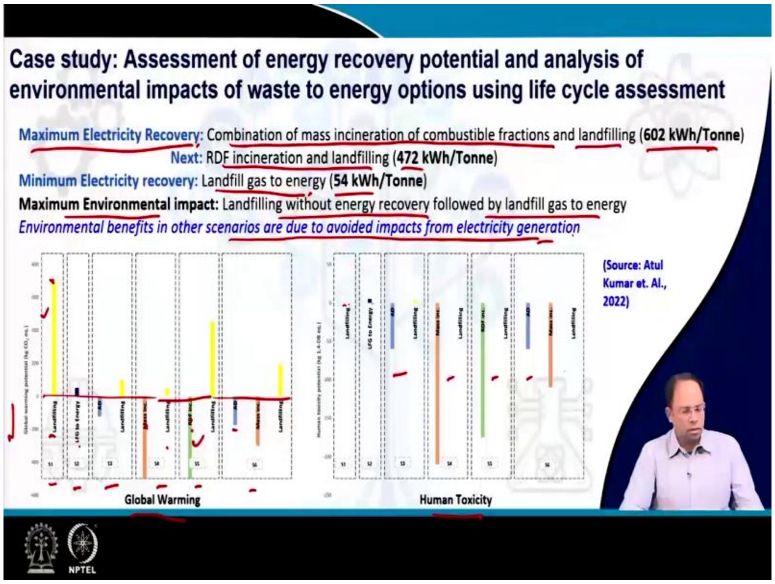

Now, coming to summarizing the results, you can see maybe the size of the slide is a bit small, but you can take a look over here we can see these are the different scenarios S1, S2, S3, S4, S5, S6. S1 is land-filling S2 is LFG to energy landfill gas to energy, S3 is anaerobic digestion and land-filling, S4 is mass incineration and land-filling, S5 is RDF and land-filling and so on.

So, this is the baseline and above at the positives and below other, you can say that this is the amount of, CO2 which is generated. The first one is about global warming. So, land-filling results in emission of CH4. So, that is why we can see that this is the amount of methane that is being generated on landfill gas that has been generated.

Whereas, for the other processes, aerobic digestion, it does not generate gas but because of aerobic digestion, I am creating energy which through indirect emission would have generated energy. So, everything that you see below these are in minus or negative terms that means these are avoided emissions. That has been possible because we are doing RDF or incineration and so on.

So when I take the overall thing we can say that which one is better, which process is better in regards to the global warming potential. So just to take a look maximum electricity recovery in all this scenarios that were checked, it was found that the combination of mass incineration of combustible fractions and land-filling, generated in the maximum amount of energy that we can generate, which is 602 kilowatt hour per tonne.

Whereas, the second best option was RDF incineration and land-filling, which came to around 472 kilowatt hour per tonne, whereas the minimum electricity generation was in the scenario where only landfill gas was converted to energy, where we were able to get only 54 kilowatt hour per tonne.

Now, considering environmental impact, the one which is the land-filling without energy recovery followed by landfill gas to energy are the ones which are having the maximum energy impact. So, landfill without energy recovery, the standard open dump site land-filling, that has got the highest environmental impact that is obvious also, but here it is done in a more quantitative and a more thorough manner.

So, that we do not make any sort of mistake by missing out some of the internal processes or some of the each characteristic of detail like both direct and indirect emissions that result from this particular process. Environmental benefits in other scenarios are due to avoided impacts from electricity generation.

So, all the benefits are because of avoided electricity generation. So, here it is human toxicity, again, we can see that land-filling and LFG to energy has got some amount of very little but some amount of human toxicity effects whereas, all the other processes are overall positive because they result in electricity generation which prevents toxicity generation.

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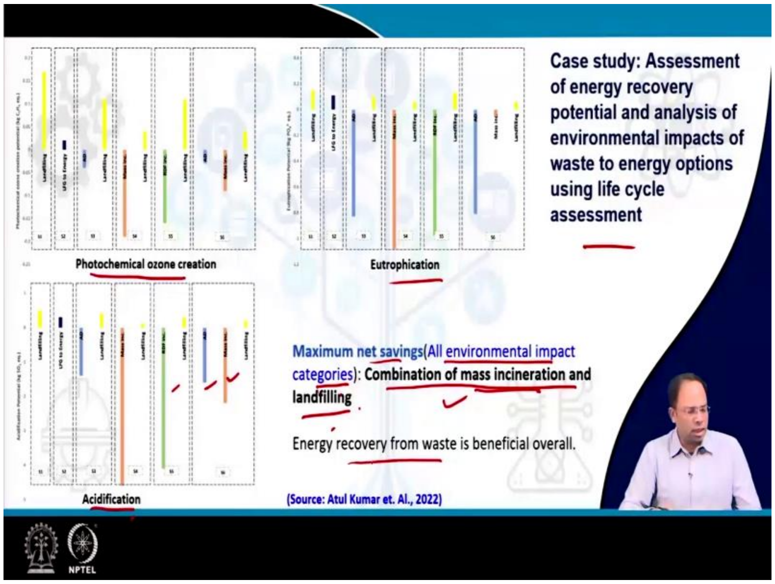

So, which avoid where we are talking about avoided toxicity generation. Similarly, we have the analysis what is done for photochemical ozone creation, these are all harmful effects, Eutrophication, Eutrophication is also an harmful effect, Acidification. So, these are all has been compared and it was found that the maximum net savings all were considering all environmental impact categories, which is the best option, because, these are all savings that is happening.

So, combination of mass incineration and land-filling is the best option to choose from. So, that means, if I use mass incineration and land-filling, then it shows as per LCA analysis, it gives the best waste to energy option. So, there has been a lot of doubt regarding waste to energy technologies, particularly incineration and pyrolysis, gasification and so, on.

Usually, it is understood that if everything fails, then we will go for this kind of pyrolysis. But this study actually shows that, of course, if I consider both avoided impacts as well as direct impacts, as well, in that case, energy recovery and also energy recovery as well then energy recovery, like in mass incineration and all our options which could be considered by urban local bodies.

So, this is what this particular case study also highlights that in future we can look for energy recovery from waste as a beneficial option, particularly this incineration and all this pyrolysis gasification could be beneficial options for urban areas in India.

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So, these are some of the references you can study.

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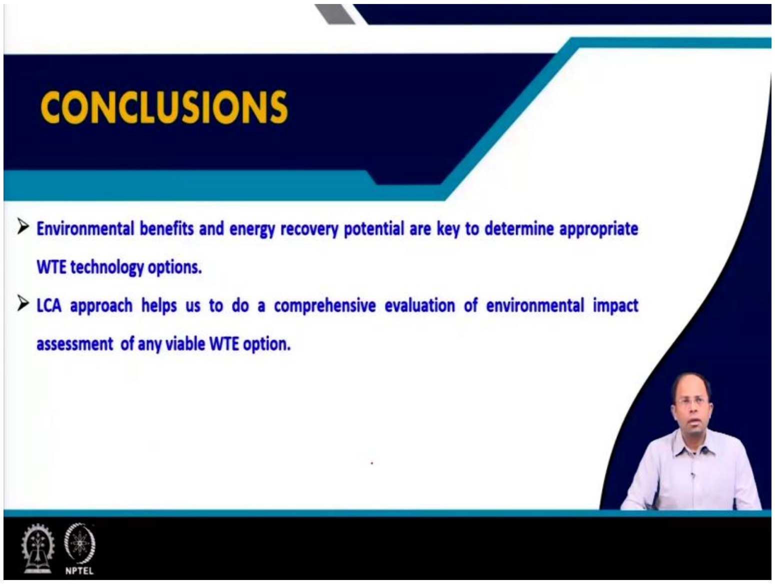

To summarize, environmental benefits and energy recovery potential are key to determining appropriate WTE technology options. And LCA approach helps us to do a more comprehensive evaluation of environmental impact assessment of any viable WTE option. Thank you.