

**Plastic Waste Management**  
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**Lecture - 36**  
**Plastics Resource Recovery and Circular Economy**

So, hello and welcome to this last week of Plastic Waste Management course. So, this is the week 8 and as you know from the course outlined in this particular week, we will be focusing on Plastic Resource Recovery and the concept of Circular Economy and how that relates to plastics.

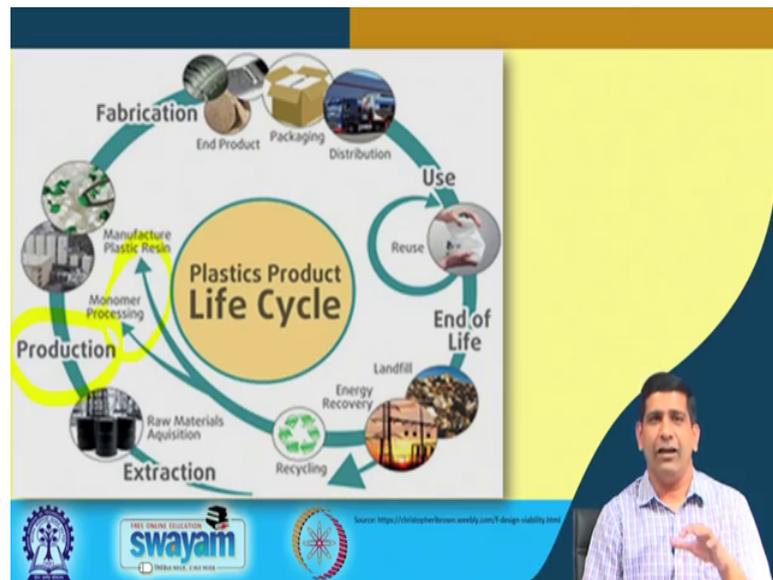
So, as you know resource recovery means trying to like recover the resource from plastic waste and how it fits into the big picture circular economy, which is a new buzzword circular economy, lifecycle analysis; these are kind of newer words which is there in our environmental domain as of today.

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So, again the concept that will be covered is resource plastic resource recovery, plastics and circular economy so, that is what we will be focusing on this week. And so, this would be as you know this is the last week, again as like any other week we will have 5 videos of half an hour each and there will be a quiz and of course, you have discussion forum for all the questions and answers and any queries; so, ok.

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So, let us get started. So, when we say a circular economy, resource recovery or of a plastic product, we are talking about essentially lifecycle of that plastic product. Now what is life cycle? As this particular picture is trying to illustrate life cycle means you start from the very beginning life cycle.

So, you start the concept is cradle to grave or cradle to cradle, and we will I will explain you those concept in a minute. Those of you have taken a lifecycle analysis course like we had one offered through NPTEL as well which was run twice. So, if you have taken that course and you know that, but if and even if you have not taken that course does not matter, we will be covering the basics in this particular video here as well. So, in terms of and those of you who have taken that course it is kind of a revision for you.

So, when we say lifecycle analysis we are talking about starting from very beginning, so, extraction of the raw material. So, you get the raw material acquisition which is you are trying to get the raw material when we from the mines we get this raw material, then we have to produce. So, there is a production phase we are making some production we are making things. So, in terms of a plastic products, the raw materials will be essentially plastic comes from oil based, isn't it? There the traditional plastic is oil based. So, it is a crude, petroleum. So, that is the raw material.

From that we have several plastics different types of plastics being formed and that is what the formation of different types of plastics and with those plastics, we are

fabricating different products. So, once you have the basic plastic like the plastic the raw material, from there you are making a product. So, you are fabricating you are making a lot of products, you have got a lot of end products coming out of plastic based which can be essentially plastic and could be mixture of plastic with other materials, then packaging, then it gets distributed through the wholesalers to the retailers.

And then finally, it comes to you our human like how in our houses, in our offices and a different application that we use it sometimes they reuse it within our system as well. So, there is a reuse like you buy you get a big bag you went to a pantaloon store or as a big bazaar and those kind of stores and you get a bag which is a good quality bag and you keep on using that bag for quite some time; when it gets bad, but it gets bad when it starts tearing away, you throw it.

So, there is a lot of reuse happens which is a kind of that particular product. And once the reuse is done we are not using it anymore, we put it in an end of life. So, we started from extraction from the very beginning and then finally, we went to finally, to the end of life. So, that is your cradle to grave. The whole concept of cradle to grave is cradle is when the baby is born we put it in a cradle. So, that is the beginning of any particular product and grave is the end of life.

So, at the end of the life, we put the bodies in a grave, since this concept came from the western world they use grave a they use grave for the most of the cremation and so that is why there this is called cradle to grave. In recent times so, this is the crib like end of life it goes to landfill or it can go for energy recovery. So, that is your like an end of life of a plastic product or for a for that matter any product lifecycle analysis.

In recent times, a newer concept is being investigated quite extensively in recent past, where we are trying to like recover the material. We are trying to recycle the material, we are trying to bring it back into the different pallets which we talked about in the earlier week if you remember we are talking about the plastic recycling. So, we are we are trying to do the monomer processing, we are manufacturing those plastic resin that is I think that was in the last week we toyed with the beginning of the last week, we talked about that.

So, and then when you do it and you bring it back into the production so, you have these kind of a stuff which you bring it back into the production. So, far you take this and you

bring it back to the production phase that becomes your cradle to cradle that essentially becomes your cradle to cradle. So, you had it started from the very beginning and then you are again making it back into the economy. So, that is the cradle of cradle concept is that circular economy concept which will explain talked about in more detail in this particular week.

Circular economy which you will be hearing a lot of buzz word these days. One of the problem that we have in environmental jargons is that we start using certain terminology whether we understand that or not. These days you will see the circular economy used a very everything, you will hear circular economy added to it. Similarly earlier like last 5 to 10 years, sustainability was added to everything even today it is added to everything. Although many times people when they talk about sustainability, they essentially mean durability. Something which lasts longer period of that is not sustainable that is durable.

Sustainable means it sustainability has three pillars economics, social and environmental and the definition of sustainability is that you make use of resource in such a fashion that our future generation should have the access to similar resources for whatever they want to do with that. So, that is sustainable where you do not use up all the resources.

So, the future generation does not have anything to work with so, that is the concept of sustainability with an angle of environmental performance which is done by lifecycle analysis and also looking at social LCA and Life Cycle Costing which looks at economics part. Social LCA we will look after the social part. So, there is a social angle there is a environmental angle and there is a economic angle and then all these three that is why it is all three pillars of sustainability, that makes the concept of sustainability. But as you will see and many meetings many conferences even some talk shows and other stuff people will use sustainability just because they want to use it although, they do not really understand what really sustainability is.

So, that is that happens not only in India everywhere that happens in many places in the world. So, the so, we need to understand that is that is the reason why I wanted to have a week devoted to this whole concept of circular economy, linear it will talk about linear economy circular economy how it relates to plastic because these buzzwords you will see a lot and you should have someone who has taken a plastic waste management course should have understanding of that and that is many people do not have it.

So, those almost 9600 students who are registered for this course, I really want them to have a clear understanding of what is the concept of lifecycle, what is the concept of circular economy, how it relates to plastic waste and plastic recycling and all that ok. So, let us go to.

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So, when we have talked about this the waste management that we started with in terms of any waste management practice including for plastic waste, the concept is we try to go in this inverted triangle that is the path we want to follow. Whether we are being able to follow or not that is a different matter, but throughout the world whenever you look at any waste management hierarchy, whether it is a municipal solid waste, whether its construction and demolition waste, whether it is a plastic waste. Plastic waste is essentially a subset of municipal solid waste. Because at most of the places what some will come from industrial and other sources that is also we call IC and I waste which is industrial commercial and institutional waste that is another term used in many parts of the world.

But in general when we talk about plastic that we kind of discussing in this course or in general what you see in media and other discussion, the plastic waste that we are referring to is essentially coming from municipal solid waste. So, the hierarchy for in general for waste management is you start with source reduction, you try to reduce the

waste that is being produced so, that is the source reduction. If you cannot do that whatever it is produced, let us try to reuse it.

If you cannot reuse it, let us try to recycle which we talked about in detail in the previous week how to do the recycle, different types of recycle. Cannot be recycled like you know at PET, LDP they are pretty good in recycling, but there are certain types of plastic which is not that easy to recycle hey. And when you go for recycling they may actually end up being more harm to the environment, then when we say more harm because the time type of energy and water requirement to make it recyclable. You if you do that lifecycle assessment, you may see that actually it is not really doing much environmental good.

In fact, you are probably trying we were ending up spending more your environmental footprint of recycling process is actually much higher, then making the virgin plastic of that particular type. So, so then you go for incineration or some of those kind of resource recovery part. So, that is you go and try to do some sort of resource recovery. And then things which cannot be recovered cannot be incinerated finally, landfill which is the least preferred way of like we want to have least preferred in terms of landfilling and this is the most preferred in terms of the source reduction. So, this is what we try to achieve. Unfortunately what is happening is kind of the opposite. As you know most of the waste is ending up in Indian contest is ending up in the dump site which is a not a engineered landfill. In fact, from a technical point of view we should not even call that a landfill; if they are not landfill that that Dhapa it is a dump site. Dhapa in Kolkata is a dump site, Deonar in Mumbai is a dump site it is not a landfill, Okhla Bhalswa or Gazipur; those are dump sites in Delhi they are not landfills.

In from a technical point of view, they are not landfill although we call it landfill in the mid in the newspapers and other stuff you see that being called a landfill, but landfill is actually an engineered structure which has a liner, which has leachate collection system which will have a gas collection system, which will have gone water monitoring system is strong water this system. So, there are a lot of all the different aspects of civil engineering actually goes into making a engineered landfill, it is a geo environmental, a lot of hydraulics is involved.

So, geotechnical engineering, environmental engineering even foundation engineering everything kind of in; its goes into the design operation and maintenance of a landfill.

So, but the what we have is in most of the places it is essentially it is a dump site where the wastes are ending up and most of our wastes are actually ending up in the dump site. But although it is the least favoured land filling, but that is where the most of the waste is ending up. And that is happening in other countries as well not only in India even in US close to 50 to 55 to 60 percent of the waste in US is also going to the landfill

So, in India it is more than 90 percent, but in the US also around 55 to 60 percent is going to landfill. Some European countries especially Western European countries like Denmark, Netherlands, Austria Germany Sweden (Refer Time: 13:41) and other places they are they have actually reduced their landfill into in single digit percentages. So, less than 10 percent, but most of the other countries are still have to put a sizable, but those are landfills those are engineered landfills

In India, we still have engineering we have still have the dump sites which is kind of a concern. So, but this is how in typically wastes and since the plastic waste is part of the wastage part of the municipal solid waste in plastic waste also. We see a similar hierarchy. We see more and more of plastic going to the landfill as other than the ones which is easily recyclables which your PET SDP they do get recycle, but many of the other type of plastic do end up in the landfill site or can go to incineration plant as well, only thing is that when you have plastic in the incineration plant, you have to be careful in terms of the temperature of the operation of the plant to make sure you do not produce dioxin purines and those kind of contaminants.

So, being said that let us move on. So, just wanted to kind of give you an idea of how the wastes is managed in general.

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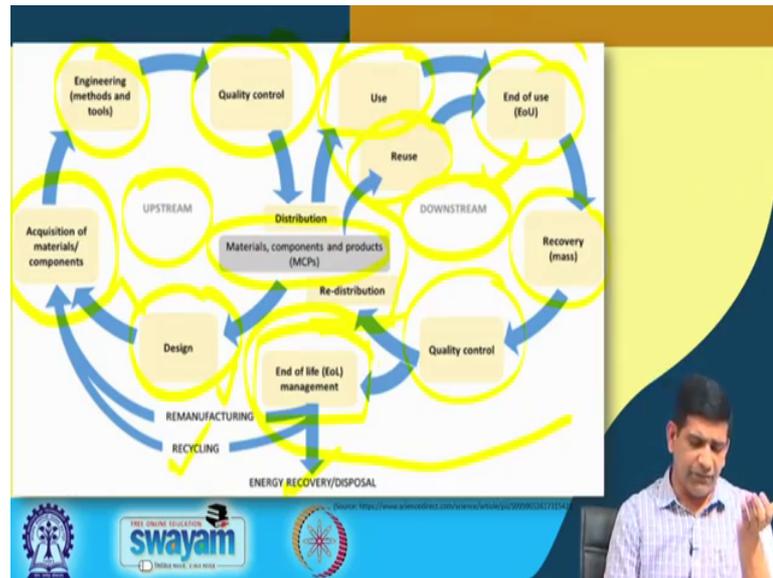


So, that was in general now if you look at the plastic waste in particular. So, if you want to try to recycle plastic waste and try to create the plastic waste recycling value chain so, you start with consumer which is you have the waste producer like people like you and me and some institution factories and other places where the waste is essentially produced. So, it is the consumer or the waste producer that is from where we start with

Then there is waste handling, you handle the waste and sorting you have a sorting for different types of plastic you took at the recyclers place and then in between you have when you go for consumer which is lost to other waste stream in the environment. So, if we will lose part of it will not all be get collected there will be some loss to export or incineration then when you do for sorting rejects not fit for recycling even for severely in sorting you will find several things which is kind of reject and for from recycling..

Once you kind of produce the new product, then you have you can replace the input of version plastic with a newer plastic that you produce that kind of goes again to the producer phase. Then we have a plastic consuming company, in between here when you are producing the waste you have when you are either using the virgin plastic or if you are using a recycle plastic, you make the product there will be some production waste. So, all those things comes in picture in terms of the plastic waste recycling value chain different aspects of that plastic waste which we see in terms of how they how it moves in an economy.

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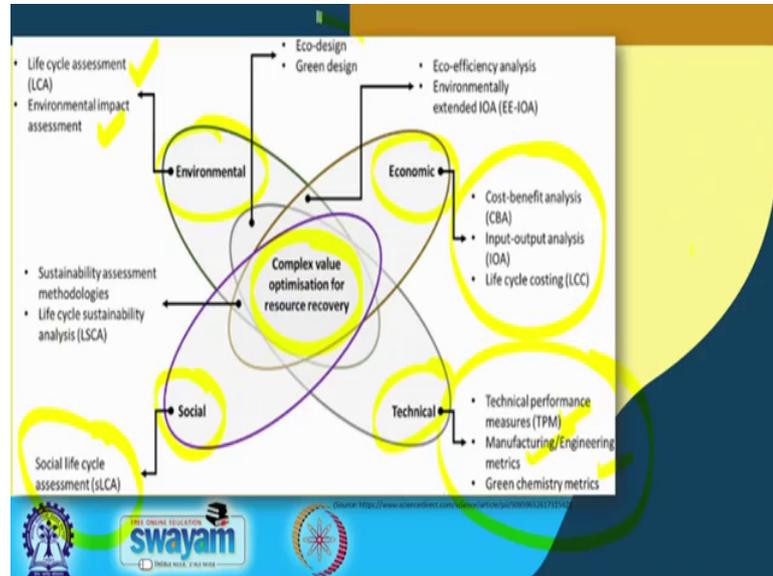
So, if you look at kind of in a cyclic way of how things are moving. So, you start there is a in a broad picture, we can call p things at upstream and downstream. Now we will talk about that what is upstream what is downstream. So, upstream is say you have your material, components and products. So, you have certain material, components and products you design stuff when you design your try to get acquire material and components, you use certain engineering methods and tools, you do some quality control and then you come up with a product. And that product is distributed it is used and then finally, once it distributed.

So, this part of it well like we are making the product, you are getting it ready for the market that is your upstream part. Then you come to the distribution, you put it in use or and reuse, then you have end of use you have tried to recover the material. Here also you will have some quality control you may have some redistribution of the material, going back into the economy, and some which cannot go comes to end of life management. In the end of life management, there could be offset aspect of remanufacturing or recycling or energy recovery or disposal.

So, this part here is our kind of what is downstream part. So, upstream part is kind of making acquiring material, using the design come up with a new product. So, that is your upstream. Once the product is in use end of life and then, things associated with end of life that becomes our downstream. So, that is how these are again at kinds of some

nomenclature which is defined for different types of processes that happens in a plastic economy or in general for any economy in terms of when we look at its lifecycle part.

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So, whenever we go for any of these design, there are it is not an easy process it is a complex process and whenever we try to go for anything like a sustainable or green and other stuff, as I was telling you earlier, there are different aspects associated with that. One aspect is of course, says it as part of sustainability we were talking about the environmental issues we are talking about the economic issues, we were talking about social issues and then we are also looking at the technology technical issues, which will be more in terms of whether it can really be done the operational challenges of doing different stuff.

So, in terms of these four broad area and what you need to do as you can see in this picture over here, we have economic and social, we have environmental and technical, things overlap and finally, there is if there is an area where we have all four kind of has the presence social, economic, environmental, technical all have that presence and but we need to have an optimization of coming up with an optimized stuff.

Something very good for the environment but very difficult to operate very costly does not is not will not be acceptable to society of that particular, because of their own beliefs and then tie with the way they live their life, then that that particular product or that particular process has no meaning. They may be great process a great product, but cannot

really be accepted. So, then we have to look at all these four parameters and based on that parameters, we can come up with some like it is a complex optimization problem of the resource recovery.

So, individually what they really mean. So, there are as you can see on the sides there are certain parameters listed. So, let us look at that parameters to make some sense out of that. So, for environmental as we just talked about in a couple of slides ago, lifecycle assessment environmental impact assessment, those are the two broader area of a looking at the environmentalist stuff. EIA which is the Environmental Impact Assessment which probably many universities offer courses on EIA.

EIA is mandatory for most of the product projects to be done in India or in abroad as well. So, EIA has a localized kind of focus. So, say for example, I am sitting at a town of Kharagpur in West Bengal. So, you say there is a proposal to set up a new factory few kilometres from our campus, now we will do an EIA to find out what the changes what is the impact that is going to come with the settlement with the construction and of operation of this particular the factory which is going to come here.

So, we look at the baseline, will look what would potentially happen we will do some baseline calculation will collect some sample, based on the type of factory which is going to come, what kind of pollutants will come out, how much energy will be required, how much water will be required. So, based on then we do we come up with our EIA Environmental Impact Assessment. LCA which is kind of a bigger brother of EIA, it goes much broader EIA, is a localized thing it is a local focused localized focus study.

LCA is a global aspect where you are looking at in a global perspective. So, you go from very like a cradle to grave and have a global perspective. So, because things do move around so, you are using certain material at say you know at this particular place which was made in China or made in Germany or made in Japan and so, it had while the manufacturing of that particular material. There was certain environmental footprint associated with that and which is not taken into consideration when we are just using them and do that EIA study for this particular factory in say Kharagpur area.

But if we are going for an study we will have to take that into incorporation because LCA kind of talks about resource acquisition, material acquisition from the very beginning and all the way to the disposal. So, that is your acting as a much broader

concept, much bigger concept, my global focus EIA is more in a local focus. So, that is what the difference between, but port looks at the environmental aspect. So, that is a EIA and LCA

Then in terms of like hey when we talk about the greener stuff which is kind of smaller like oval shape over there we will get there in a minute, let us look at the bigger prime bigger picture of others then we will go into those oval shapes which is in the middle so, economic when we talk about economics. So, we talked about environmental already. So, economic we try to do that using cost benefit analysis, by doing the cost benefit analysis input output analysis or life cycle costing.

So, that is what how we look at the economic analysis. So, we can do a cost benefit which is CBA input output analysis or life cycle costing that is a economic focus technical aspect where we look at what is how in the in terms of the technical performance. So, there are some parameters of technical performance measures, manufacturing engineering metrics, green chemistry matrix. So, that can be used for the technical aspect.

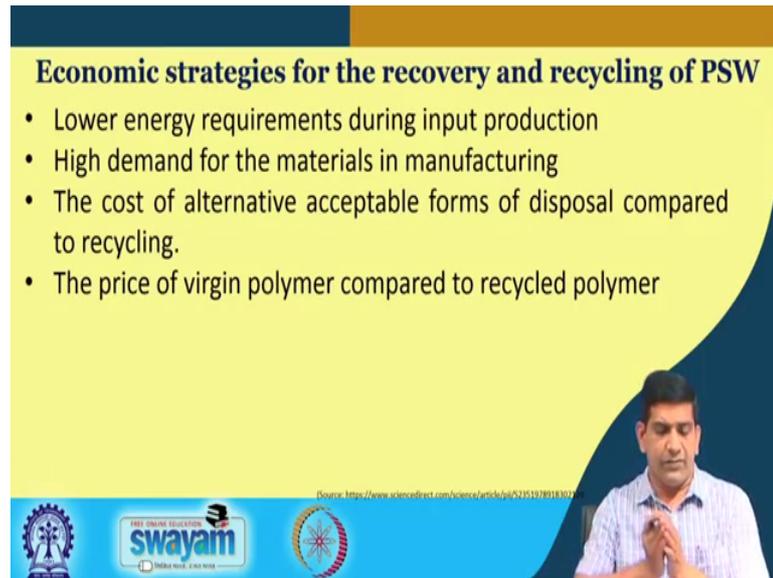
Finally for the social aspect there is a social life cycle assessment so, which has been developed by UNDP which very recently a few years back it came in. And we are still learning how to do CCA, social LCA which is a little bit different then I would say the concept is a bit different and we have to really learn and start using it. So, that is the bigger picture of the 4 bigger area.

Now, in terms of the overlap areas; so, when we look at there is a small ovals in the middle that two of them. So, here in the in terms of the point we are looking at eco design and green design, which kind of works with environmental and technical both aspect. When we look at environmental as well as economic we are looking at eco efficiency analysis environmentally extended IOA which is Input Output Analysis.

So, that is your that is their environmental and economics in terms of a environmental and social aspect we have certain sustainability assessment methodologies life cycle sustainability analysis. So, that gives us social and environmental and then technical we talked about that. So, in general so, these all kind of leads to a complex value optimization problem for the resource recovery.

So, that is how things needs to be put into perspective. So, whenever we go for a kind of a resource recovery project from an environmental point of view, we have to look at these factors, we have to look at the environmental issues, we have to look at the social economics and technical operational issues whether it is going to work and how it is going to work. So, so let us go further.

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**Economic strategies for the recovery and recycling of PSW**

- Lower energy requirements during input production
- High demand for the materials in manufacturing
- The cost of alternative acceptable forms of disposal compared to recycling.
- The price of virgin polymer compared to recycled polymer

Source: <https://www.scribd.com/document/512137911/PSW>

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So, now the economic strategies for the recovery of recycling of plastic waste is low energy requirement during input production. If it is a low energy requirement high demands for material in manufacturing, the cost of alternative acceptable form of disposal compared to recycling we have to look at that the price of virgin polymer compared to recycle polymer.

So, sometimes you need to play with the rules and regulations and like bylaws and economics to make sure that things work for our whatever we want to get it done, it is kind of a trying to influence the market in such a way. So, that by making legislation in such a way so, that recycling and also the resource recovery is encouraged in terms of the plastic waste.

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**Environmental strategies for the recovery and recycling of PSW**

- Enforcement of Producer Responsibility Regulations to encourage collection of plastic wastes
- Enforcement of national-wide law on plastic waste recycling
- Legalization of selective collection performed by waste pickers from households, retailers, dumpsites etc.
- Enforcement of environmental awareness programmes on the importance of plastic waste recycling
- Enforcement of waste segregation at household level
- Creation of quality standards and certification schemes for plastic recyclers

(Source: <https://www.sciencedirect.com/science/article/pii/S2351978918302129>)

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So, in terms of environmental strategies for recovering and recycling of plastic solid waste my classic solid waste.

So, what can be done enforcement or producer responsibility regulation to encourage collection of plastic waste? So, put a producer responsibility regulation. So, producer is responsible or liable for the waste that they produce. Now we have to make sure that waste there is an infrastructure for waste management, but the producer has to do it we can there could be monetary charges on that as well enforcement of national wide law on plastic waste recycling because state wise it becoming difficult, there are borders around such things can move across the border to avoid that we should have same rule throughout the country.

Legalization of selective collection performer, waste pickers from household retailers and dump sites. So, because they are already collecting it so, why do not we just legalize it? Enforcement of environmental awareness program on the importance of plastic waste recycling. Enforcement of waste segregation at household level creation of quality standards and certificates his scheme for plastic recycler, and I think that is very important and that is where institutions like us can play a role in terms of creation of a standard quality standard and technically strong short term programs where we can train the main power men are men power working in this particular area.

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**Market strategies for the recovery and recycling of PSW**

- Formation of polymer recycling stream end markets.
- Closer engagement of recyclers with one another along the supply-chain
- Recyclers to deal directly with municipalities, sorters, scavengers and households
- Existence of market systems relying on recycled-material throughput involvement
- Transnational cooperation on waste plastic recycling

Source: <https://www.sciencedirect.com/science/article/pii/S235278181302>

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So and then there are market strategy, look at the market formation of polymer recycling closer engagement of recycling with supply chain, directly with municipalities if existence of market system. So, those technical cooperation on waste plastic recycling.

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**Social strategies for the recovery and recycling of PSW**

- Use of incentive schemes to motivate plastic recycling at household levels
- Efficiency of the municipality, private waste contractors or informal waste collectors in waste collection
- Introduction of plastic waste segregation at household level for recycling purposes
- Increasing consumer awareness on plastic recycling
- Education of the households/community on the relevance of informal waste collectors in the supply-chain

Source: <https://www.sciencedirect.com/science/article/pii/S235278181302>

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So, all these things needs to be looked into this is a social strategy as well like how to motivate people to do the plastic recycling at household level, source segregation and household level. Efficiency of municipality private waste contractor in waste collection introduction of plastic waste segregation at household level, increasing consumer

awareness, look education of the household community and the relevance of informal waste collector in the supply chain

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**Technical strategies for the recovery and recycling of PSW**

- Improvement in recycling technology and infrastructure e.g. extrusion, blow moulding etc.,
- Improvement in size reduction technologies
- Improvement in the sorting technologies
- Designing of products for recyclability
- Ensuring material applicability in manufacturing processes

Source: <https://www.sciencedirect.com/science/article/pii/S23527818302>

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So, all those things needs to be tried in into the into our system. For the technical strategies you look at the improve and increase settling technologies, improvement in size reduction improvement in shorting, designing for product for recyclability, ensuring material applicability and manufacturing process or recycle materials should not come there. So, based on all these different aspect we will continue our discussion of this plastic waste resource recovery and so, we will close this video right now.

And we will continue this and similar discussion in coming videos and then we will get into the circular economic concept. So, again this is the last week number 8. So, we are almost there the course this is the way 8 week 8 video 1. So, we will have another 4 videos and the course will be over. So, I hope you are enjoying the course if and many of you I see that many of you have registered for the exam, if this date is still there please do that and take advantage of the exam so, that you can get a course completion certificate.

So, thank you and I will see you again in the next video.