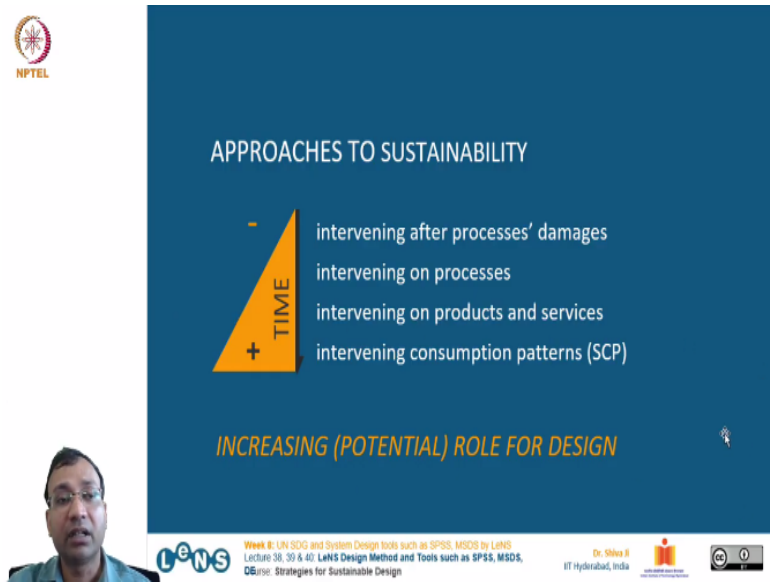
Strategies for Sustainable Design
Professor Doctor Shiva Ji
Indian Institute of Technology, Hyderabad
Lecture 29
LeNS Design Method and Tools such as SPSS, MSDS, DE

Hello everyone, in this lecture we will discuss about LeNS Design method and tools such as SPSS, MSDS and DE. Well, a LeNS is learning network for sustainability, it is an international forum where a group of academicians, researchers, scholars such as you have become part of it, they develop sustainability assessment methods, tools, techniques etcetera, they apply these into various cases from across the world, they prepare case studies, they share with each other, they publish research papers, books and other resources which are crucial for understanding of a sustainability in an overall set. Majorly targeting product design and some parts in some cases architecture also.

(Refer Slide Time: 1:09)

So, in this lecture we will discuss about evolution of sustainability within design. These are the contents, so hopping on with the first topic, increasing role of design for sustainability.

(Refer Slide Time: 1:17)



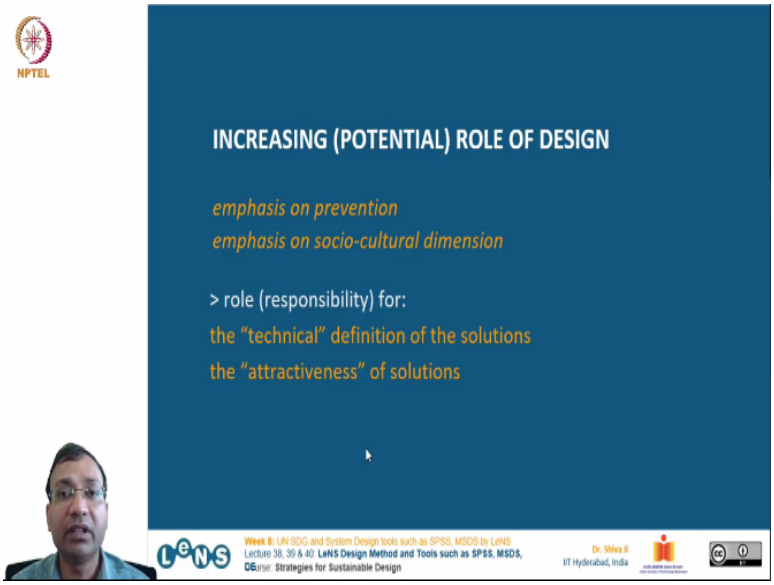
When we see the increasing role of for design intervention into the design for sustainability approaches, so the greatest intervention is possible at the time of deciding the consumption pattern, so when we are looking for some kind of product or a solution as a consumer, so that time, stage has the largest potential to minimize the consumption of resources or the energy which will follow up for to satisfy or to fulfill our needs. So, the largest potential for improvement is right there at that particular stage, so that you can see in this graphic over here.

So as the time goes from a conceptual stage till the work is done and the products delivered or the service is rendered, so from the starting to the end the largest potential is at the beginning itself, if you can correct, so remember the previous lecture what we had in the NBC chapter, so minimal consumption, minimal waste that is possible through correcting our behavior, our habits itself.

Second, intervening on product and services, so that is at the stage where we are designing or fabricating or manufacturing our product or rendering our services at that time also we can use certain strategies to minimize the impact, further intervening on the processes, so the product of the system is in place and is under operation, so even at that stage we can minimize the consumption and minimize the energy uses. Further in the last intervening after products damages.

So, for example, once the product is a used and it is left out or discarded even by adopting certain strategies at that time, for example, recycling, reusing, remanufacturing etcetera, we can minimize up to certain extent. So, we saw that the largest potential for this improvement is right at the beginning stage, so you must focus more and more in the beginning stage only, in the conceptual stage itself.

(Refer Slide Time: 3:32)



So, the emphasis should be on the prevention because rather than cure, so the cure is remedial method, once the problem has arisen then comes the cure, but prevention comes before the problem has arises, so we must go for handling sustainability through using this approach of emphasis on a prevention, so an emphasis on a social cultural dimension, so the sustainability involves all of these three aspects and it is very important to address and consider those aspects also.

Well, the rules and responsibility for the technical definition of the solution and the attractiveness of the solution. So, if you see there is a huge role for us to play over here, how we can define a situation, how we can elaborate a situation, how we can make it an attractive opportunity to deal with or to go for a certain innovative solution in any given context.

(Refer Slide Time: 4:42)

So, what does the design community in general knows about design for sustainability?

(Refer Slide Time: 4:47)

Let us see some examples, so we have this cardboard seat, so you may have seen such a product around you which use this kind of a material, so what kind of impact it can generate? Well very minimal, so that what comes to our mind in a first glance.

(Refer Slide Time: 5:14)

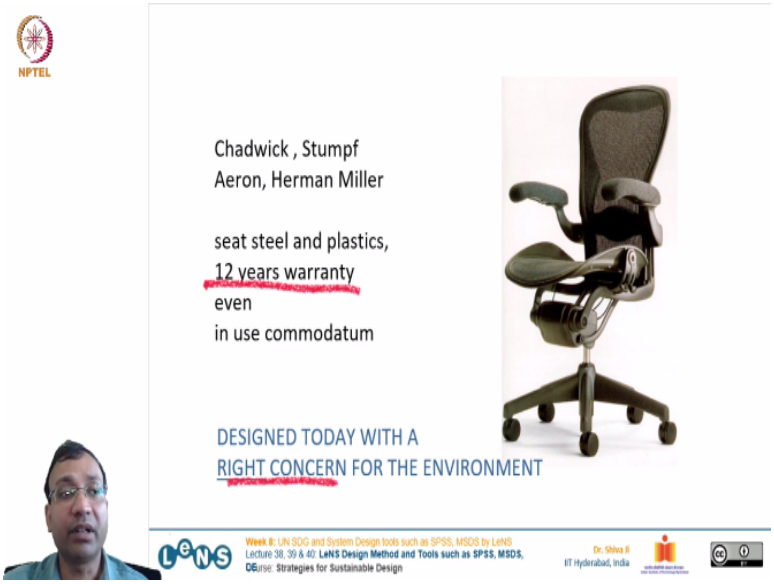
What comes to your mind after seeing this picture? It is a walnut wood a chair, it is almost a has lived 500 years of life, so is it sustainable or not because this product is taken from a tree, so if we go for a conscious evaluation of these two products and whether they are environment friendly or not, so the first one looks, this one look environment friendly, this one does not look environment friendly.

(Refer Slide Time: 5:42)

But if you compare the time and the functionality, so how many number of these cardboards are needed to render the same service which is the single product has a solved for a long period of time, so there is a factor of time in this if you see, so that is where this the product designed for a longevity an extended lifespan comes into picture, where we consider an extended, efficient utilization period of that product because once that product is manufactured and ready for use that must carry on its job for a longer period of time in order to prevent the second same product to come and replace the first one.

So how we can minimize the need of a second product up to an extended period of time that is the task over here, that is idea over here which I am trying to explain. So, you must assess your product in terms of longevity also how long it is going to serve. So, on sustainability evaluation parameters time is a very important factor, how long a product is going to serve.

(Refer Slide Time: 6:54)



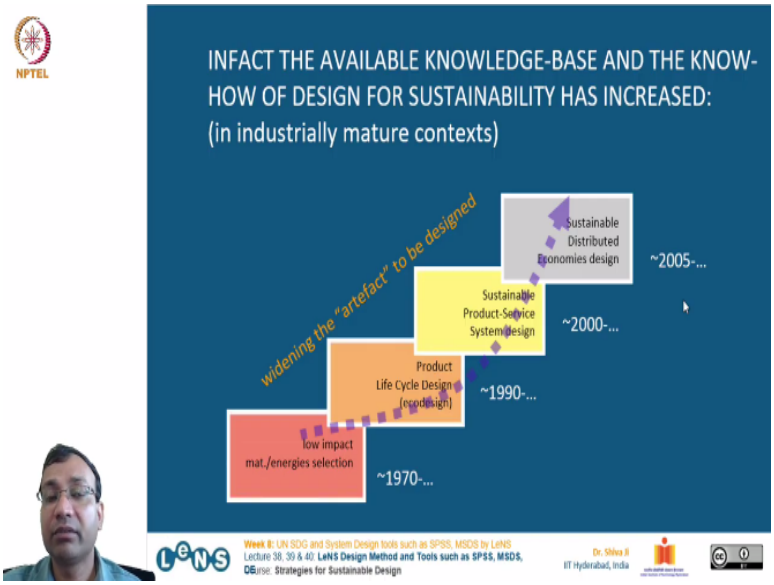
This products example I have taken from Hermann Miller, Hermann Miller is a famous furniture design and manufacturing company, so any random chair which we use in our houses it mostly lasts for 3 years, 4 years, maximum 6, 8 years or something that, but this particular chair is designed to last for a minimum 12 years and the company offers a warranty also of 12 years. So that is a very new thing in this product domain if we see, no other furniture company offers 12 years of warranty period of their product, that means the company itself is confident enough that their product is going to long for a longer period of time.

So, that is where the functionality of time comes into consideration, so there should be a conscious effort from the manufacturers and the agencies who are supplying their product, so that they make a product which is a good enough, which is going to sustain the test of time for a longer period of time.

(Refer Slide Time: 8:04)

So, how many persons within the design community would evaluate correctly the environmental sustainability through this picture, how many of you can identify which product is sustainable, which product is not, it is very difficult to understand because there are several other dimensions, the one we just now came across is the time.

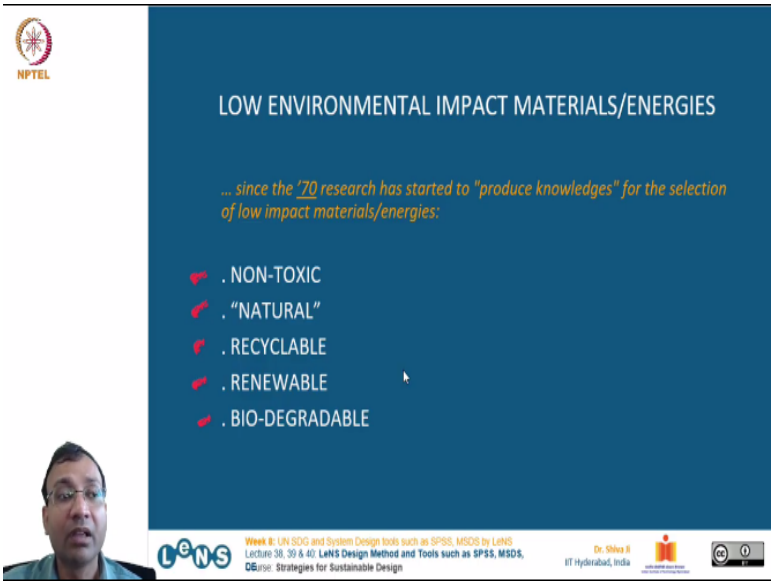
(Refer Slide Time: 8:26)



So, there should be a conscious effort and it has been developing for a quite a number of years, so in the 1970s the focus was on to a low impact designs, then in the 1990s it came

about life cycle design, then in the 2000 this came for SPSS Sustainable Product Service System design, then in the 2005 it came further Sustainable Distributed Economic Model. So, we will discuss some of these in the next slides, how it is evolving over the time.

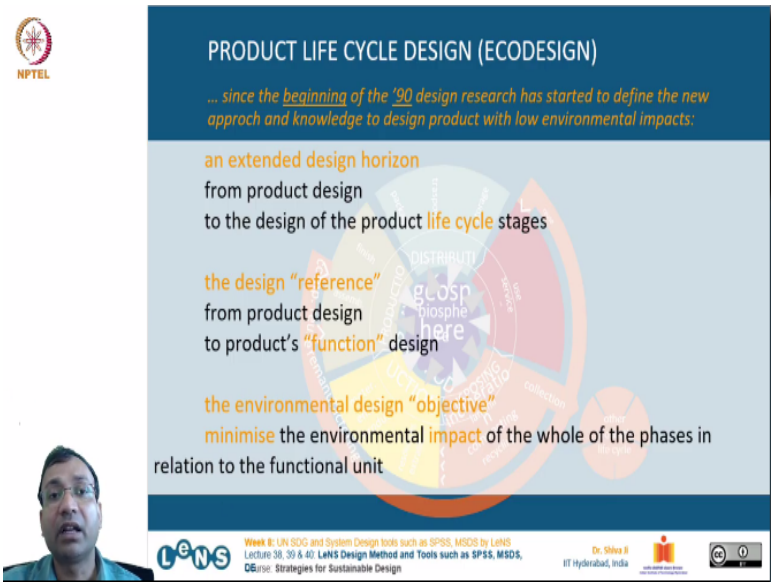
(Refer Slide Time: 9:01)



So, the product design for environmental sustainability. So let us see, low environmental impact materials or energies. So this we have been discussing in the previous lectures, so the material chosen should be non-toxic, natural, recyclable, renewable and biodegradable, because if any one of this is not met correctly, the product is going to have some kind of impact on the overall systems, if it is toxic it is going to generate some kind of a hazard for some species for example, even if a product is toxic or if it emits (())(9:37) it is a hazardous for the human usage also.

If it is less toxic it may be hazardous at a lesser proportion but it may be harmful for other organisms or if it is a non-natural synthetic then it will take a very difficult approach at the time of (())(9:59) disintegration and decay and decomposition at the end of the life cycle stage. If it is a non-recyclable again it is going to last somewhere in the landfills it is going to be there forever for a very long period, we have studied about acrylic and (())(10:17) etcetera, they cannot be degraded on their own for a very long period of time, sometimes running in up to fifty thousand years, that is a huge span of time and renewability and biodegradability.

(Refer Slide Time: 10:35)



So, how this product life cycle approach works if you see, an extended design horizon from product design to the design of the product life cycle stages, so we must not design just the product we design the life cycle stages of the product, so that the product is going to live for an extended period of time, it is a taken care of for its degradation or its disintegration, so that it can be recycled, it can be reuse and it can be dismantled and also all of these approaches should be taken care of.

Further, the design reference from product design to the products is a function design, so the product is not ultimate object what we are looking for, the object behind a product is to satisfy a need, satisfy requirement, so we must focus on that requirement or that satisfaction which that product is going to create or generate. Not the products, so we must orient our needs around the need, not to the product because product is just a means to satisfy that particular need and the environmental design objective minimize the environmental impact of the whole of the phases in relation to the functional unit. So, as we have seen the impact minimization is one of the very critical considerations and that we can try from several approaches.

(Refer Slide Time: 12:07)

So, when you see a product design life, product life cycle design which can be called as eco design also, a piece of good news it is available as a consolidated knowledge base and know-how methods and tools to design environmentally sustainable products.

(Refer Slide Time: 12:26)

But there is bad news also, the design and offer of products really with low environmental impact is still extremely limited or very few in numbers. So well there are a number of products to fulfill a need, the moment you name a product, there are n

number of solutions available, but most of them they are still having a huge impact on the overall systems, so that we must take care of in our designs.

(Refer Slide Time: 12:56)

On the third topic sustainable product service systems, win-win opportunities for companies and organization.

(Refer Slide Time: 13:01)

Let us see how, so what is sustainable product service system over here. Since the end of the 90s has been studied some business cases offering as a full package of a mix of product not owned by the customer and services showed to be capable of creating a new value decoupling it from the resource conjunction.

(Refer Slide Time: 13:21)

So, what is it we will see over here? For example, you may have seen photocopier machines, so the objective is to copy or make the xerox copies of any document or taking a photocopy of or maybe taking a print or something that, so that is the main objective but the objective is not to exactly own the xerox machine or the photocopier machine.

So, the moment you start seeing a product as a service provider, as a facilitator you will be amazed to see how a product should function, so for an extended period of time if that xerox machine, if that photocopier machine is going to serve you satisfactorily, well that is what you want. So, for doing that why you need to own a machine, so this experiment was conducted by this Xerox machine you may be aware of this company, it is a very famous company from the photocopier copying business.

So, instead of a photocopier they sold copied papers and documents, so Xerox offers a package deal and installs and maintain photocopiers, no, which is not owned by the customer and may even makes and delivers copies, the customer pays for the package, so

whatever amount of the prints or the photocopies you need well that is what you have to pay for, not for the entire machine. So the machine will be loaned to you, if you require in your premises, in your office and that machine will still be the property of this Xerox company, well you can use the facility and you can pay per print or per photocopy basis.

So, this is in an innovative business model offering ownerless photocopier machines with all inclusive lifecycle services, also the company is responsible for maintenance, operations and in case some kind of repair is needed or some supplies are needed, like addition cartridges and inks and paper etcetera.

So, the company takes care of those things, but in the present scenario whenever we buy a product, the liability of that company which has manufactured that product ends in a very short span of time which they call it as warranty period, which varies generally from six months to one year up to sometimes really in few years and after that the company does not provides free services or it does not takes care of those components or the parts of it, it just even stops supplying parts of it.

For example, the biggest electronic brand Apple which is very famous across the world, so it sells state of the art computing machines, laptops and pads and phones. So, this Apple company sells these products with a warranty of maybe six months to one year period usually and it charges X amount for an extended period of warranty.

For example, two years and after that it does not extends that warranty and leaves the customer, leaves the user in the lurch, in case something goes wrong they will charge a hefty amount to provide the service as well as provide the components or the spare parts and after five year or six year of period they just render that product obsolete, they leave it, they starts calling that model as a vintage model and they stop producing or providing any kind of service or components or spare parts needed for that machines.

So, these Apple made machines are very heavy duty, very efficient and very pricey machines, if you compare with any electronic available in the market, they charge twice two thrice, in some cases four times also, so for such a heavily priced machine is it justified to have such a short period of warranty period or stopping even supply of

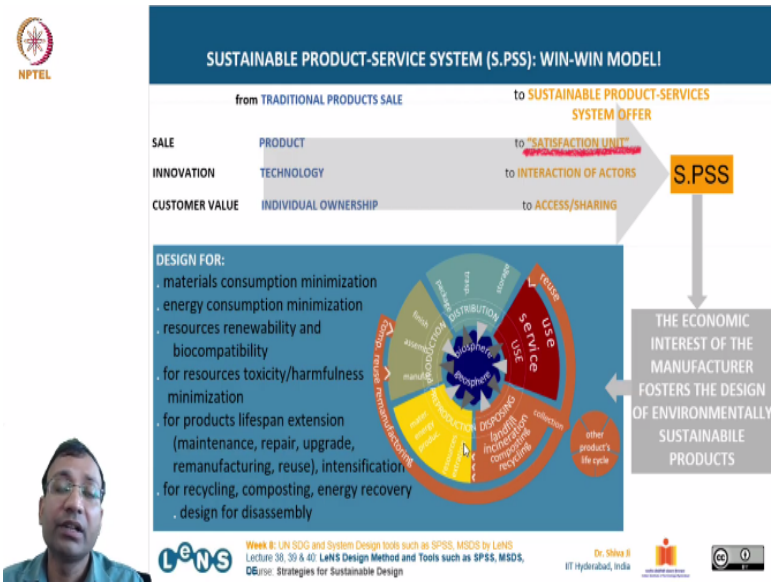
services and spare for that product. So, with this if you see Apple is really bad on doing sustainability aspects of these products and this company unintentionally or intentionally, whatever that needs to be seen or checked is promoting lot of huge electronic waste and is burdening customer to buy new models indirectly.

So, that is illegitimate way of promoting this product consumption in the masses, so the responsibility of the company, there is responsibility of the products uses also lies with the manufacturing company, it does not, it should not end with the, the moment the product is sold the responsibility of the company should not also end, so that is the consideration being said over here, what if the service of that product is sellable thing not the product itself, so what if this company they start loaning us electronic equipment and gadgets and we keep them using for X amount of time and we of give it back to the company if we do not want to use it any longer or if you want to buy a new model or something that.

So, in that case the charge will be per time usage or something that, so this concept is called another product service system, where service becomes the main criteria of payment, so in such a scenario of product service system-based approach, the responsibility of the company changes dramatically.

Now, the company is responsible to maintaining that product, so they will design their product to last for a longer period of time and that is what precisely this Xerox company did, which is a very novel idea, they made efficient machines which lasted for a very long period of time, very extended period of time. So, with the same machine they were able to render services for an extended period of time in turn saving on manufacturing several machines which may be a serving in that n number of years. So, this is called SPSS service, a Sustainable Product Service System.

(Refer Slide Time: 20:03)



So, further how you see, what is the sellable, so a conventional, traditional product sale system, so the sale is of the product but in a sustainable product service system you see in this illustration over here on this slide, the sale is of the satisfaction unit, so we are not selling the product, we are selling the satisfactory consumption or the uses of it. So, what is the innovating point if you see in the conventional product sales system, the technology is the innovative point.

But in this SPSS system if you see interaction of the actors becomes a point of innovation and what is the value received by the customer, if you see the value what we receive by buying a product is that we become owner of that product, but in this one there is a group sharing or a common sharing or the access becomes the value which we get out of such kind of satisfaction system, so this is what SPSS is and also the economic interest of the manufacturer fosters the design of the environmentally sustainable products.

So, this is how the company becomes responsible for the longer period of usage or the consumption of that particular product. So, of course, they will be maximizing the efficiency or the longevity of that product which in turn will lead us to the several aspects of several strategies of this sustainability can be achieved. For example, if it promotes reuses then we can go for optimizing on the usage part, services part, the usage part.

Further on the collection part if you are responsible disposing system it can avoid landfills and incineration in a shorter period of time, the product can be utilized for longer period of time. On the pre-production stage if you see, even the energy efficiency can be achieved because the company will be responsible to make it efficient on resources and the energy consumption and energy extraction also, so we can say if you are using the one product for lifespan of two average product, then we are at least saving the resources which were needed to manufacture the second product, second unit of product.

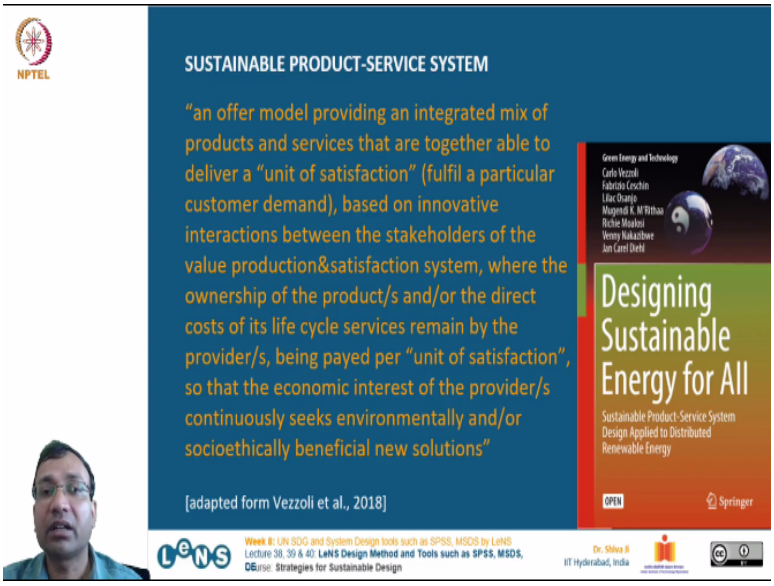
So, that is how we will save on the resource consumption also, on the production part if you see, look at the finishing assembly manufacturing, so these also will be having efficient impact and, on the distribution, the storage, transportation, packaging so there will be saving, as you can see on these parts also.

So, in an overall if you see this life cycle of our stage, there will be saving in each domain of it, so in an overall sense this SPSS has the potential to minimize the impact in an overall sense. So, the design for materials consumption minimization, design for energy consumption minimization, resources renewability and biocompatibility for resources toxicity and harmfulness minimization, for products lifespan extension, for the maintenance, repair, upgrade, remanufacturing, e-reuse, intensification etcetera for recycling, composting, energy recovery, design for disassembly. So, these are approaches, these are the strategies which SPSS has the potential to address to.

(Refer Slide Time: 23:36)

Further if you see, are the sustainable product service systems also applicable to low- and medium-income context? Let us see, are they promising models to economically faster and even social equity and are they win-win models for fostering all of the sustainability dimension? Well, it has the potential to cater to this low- or medium-income context also, it can be taken up at any level, we will discuss with some examples in the coming slides.

(Refer Slide Time: 24:05)

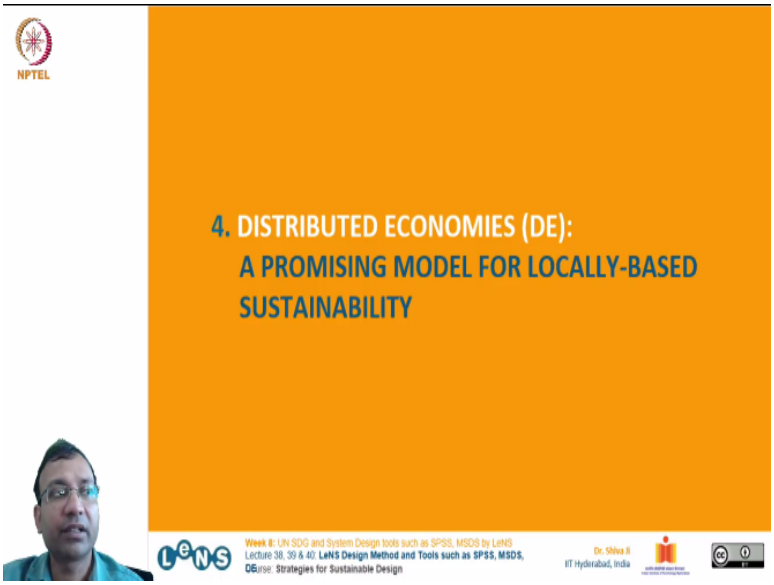


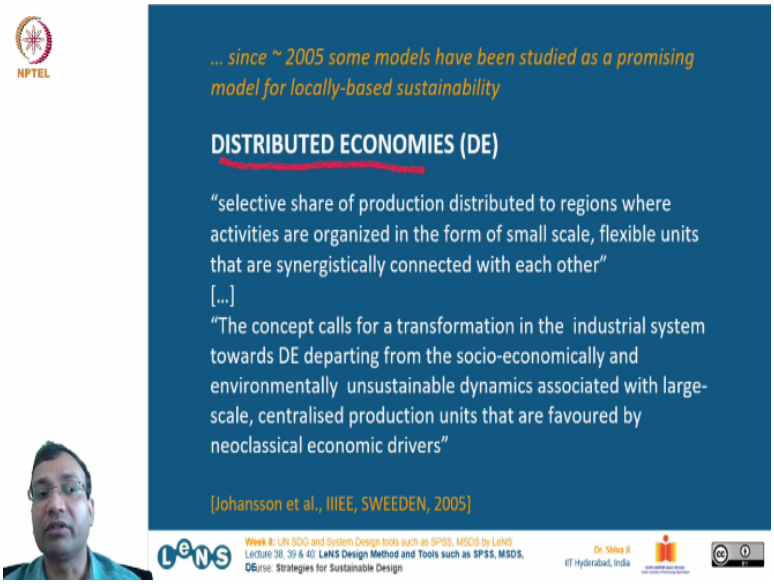
So, this book gives us an extensive detail, it has a set of articles which are written by several scientist and designers from across the world, which will be helpful in understanding this SPSS system through this book, you can refer this book when you are free after this class.

So, a sustainable product service system, an offer model providing an integrated mix of products and services that are together able to deliver a unit of satisfaction, fulfill a particular customer demand based on innovative interaction between the stakeholders of the value production and satisfaction system, we are the ownership of the product and or the direct cost of its life cycle services remain by the providers or being paid per unit of satisfaction.

So, that the economic interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions. So, this is intention of the SPSS and that is how we see there is a huge potential by adopting a SPSS system in our consumeristic product domain.

(Refer Slide Time: 25:16)

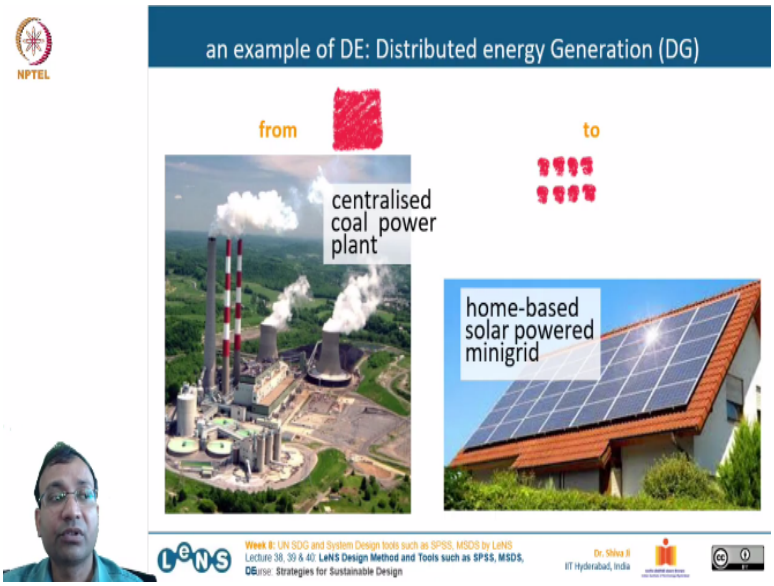




So, in the next topic let us see what is the distributed economy DE is, a promising model for locally based sustainability, so we have seen in the previous lectures how this globalization has brought several kinds of repercussions and the impact of any product which is being manufactured in one corner of the world has increased because of these indirect emissions which are happening there due to this transportation and things.

So, how this distributed economy works? So, since 2005 some models have been studied as a promising model for locally based sustainability. Distributed economies selective share of production distributed to regions where activities are organized in the form of small-scale flexible units that are synergistically connected with each other. The concept calls for a transformation in the industrial system towards DE departing from the socioeconomically and environmentally unsustainable dynamic associated with the large-scale centralized production units that are favored by new classical economic drivers.

(Refer Slide Time: 26:25)



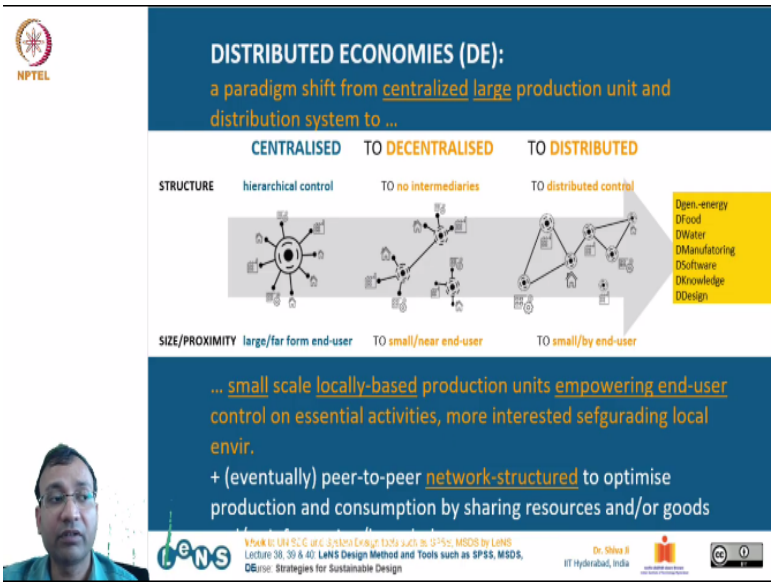
So, how it works, you see this, I would to explain you through this some examples. For example, we have this centralized power plant for example, a coal-based power plant or maybe hydroelectric power plants or maybe nuclear power plants or so on. So, they generate a huge quantity of a power and this supply for larger area but compared to this if we go for smaller power generation units, for example, a home-based solar power grids or maybe a neighborhood-based power generation grids or maybe a city-based power generation network.

So, the impact of this will be lesser, why? Because the footprint because, the ecological footprint project of this scale is very high, if you divide it into smaller units, so the overall impact can be minimized, so this is where this distributed economic model comes into the power generation system. So, this is called a distributed energy generation system, so in place of a one centralized very huge power plant, we can go for minimal, smaller unit-based power generation systems.

(Refer Slide Time: 27:46)

So, this is what it means over here, another example, for a centralized manufacturing units based on maybe one country supplying to the n number of countries, why cannot we have this economy distributed manufacturing systems also in place to have distributed manufacturing facilities at our most of the places, in almost every state why cannot we have such facilities, because for having centralized manufacturing facilities there is a larger impact on the social sector also, the workforce is forced to move from their native places to these centers or these focal points where these manufacturing units are established.

(Refer Slide Time: 28:37)



So, this is how this distributed economic model looks like, you can see in this illustration over here which gives picture of paradigm shift from centralized large production units and distribution system to a decentralized or a distributed model. So, if you see from centralized to decentralized to distributed, so these are the three verticals over here which explains this concept graphically.

So, how the structure is, so the structure in centralized system is like a hierarchical control is there, in decentralized there are no intermediaries, in the distributed it is distribution and under distributed control, so you can see this one centralized system is controlling all of these domains and here there are smaller but decentralized domains, some things are handled by this one, few things are handled by this decentralized node, but in this one if you see the units are defragmented into smaller units and all of them are operating independently in different locations.

So, they are distributed at different, larger area so that they can serve locally in an efficient manner. So, this is how this visualization is and even further consumption part for example, resource consumption, energy consumption or other types of utilization of manpower, so that also will get distributed, so the impact on the surrounding will be relatively comparatively will be very low.

For example, if a manufacturing unit is defragmented into 10 smaller units, so the kind of resources which it going to extract from the surrounding will also get distributed at those 10 different locations. So, the overall impact compared to the one bigger company which will extract the equal number of volume of those resources from the one place will also get distributed at 10 different places. So, the overall the resources needed for these 10 different places will get distributed in these 10 places, so minimizing the impact.

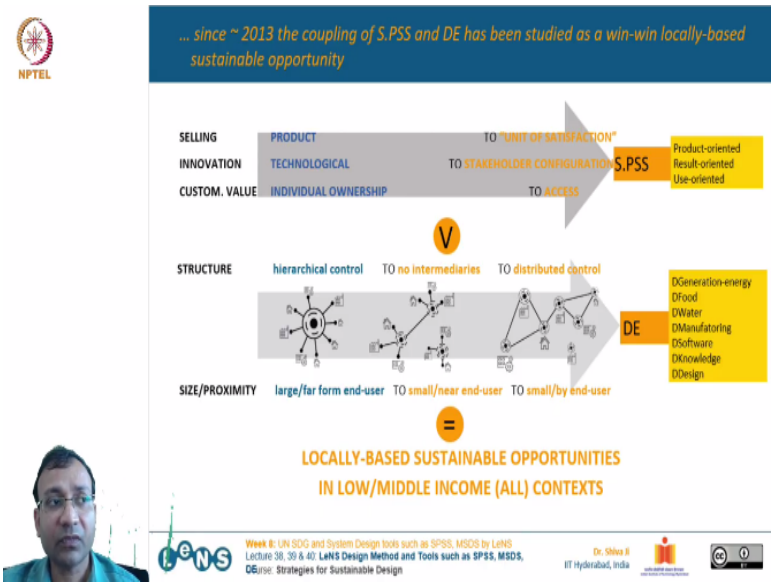
Further, energy consumption or for example, a water consumption, so a factory or maybe a bottling, water bottling plant or maybe drink manufacturing or making company which is located at one place may take huge amount of water from underground for at one place. If we distribute it at n number of locations.

So, the impact on every location will get divided by that number n. so this is what this concept is, this is what it is talking about, so for the energy, food, water, manufacturing, software knowledge for everything even for the design, if we go for distributed approach even for designing, so a design can take place more effectively in that location for wherever we are designing.

We have studied this vernacular architecture, vernacular design, so that particular design search to that place, so the resource person from that area may be able to understand that philosophy of vernacularity in a more effective way. So that person can help building the design process or the design methodology in a more effective way, so this is what it looks on the size and proximity, if you see the centralized system works in a very far from an end user and in very large format, this decentralized system works to smaller scale but near, almost near to the end user but this one work as even smaller level and by the end user, so this is where this difference is.

So, small scale locally based production units empowering end user controls on essential activities, more interested safeguarding local environment, so this is how this concept looks of SPSS.

(Refer Slide Time: 33:00)



Further when we see over here, so the selling point from conventional approach, from product to unit of satisfaction, for innovation from technology to stakeholder configuration, customers, value, individual ownership to access to that product or services. So this is what SPSS is and compared to this is what this distributed economic model is, from hierarchical centralized model to a distributed model. So, these are the two philosophies what we were discussing in this lecture. So, locally based sustainable opportunities in low middle income are kind of all context, so which can be utilized.

(Refer Slide Time: 33:42)

So, one more example I would to show you here is about this off grid electric system. It is a home based solar system to provide power to the families. So, this M-Power company offers to Tanzania rural people a solar home system SHS, which includes the hardware to generate solar energy, solar panel plus storage plus wires. Energy using products EUP two lights, phone charger etcetera.

Customers pay as pay per period on a daily basis, off-grid electric retains the ownership of these SHS and EUPs. Cutting initial and life cycle cost of SHS hardware makes it accessible and sustainable in time to low-income people and organizations. In an overall sense for everybody for example, harvesting solar energy is a very green concept but it comes with technical issue of maintaining after battery part, which is going to store that electricity power for consumption in the nighttime.

So, if the company has the ownership of that batteries, those batteries they will be taking care of then extended longevity maintenance repair if needed or even replacement if the need is. So, if the ownership remains of this product with the company they will be in a better position to keep it running for a longer period of time but we have seen how this novel approaches, this was adopted even from several State Governments of India also a few years ago but whoever have bought these products, now these products are thrown, they are not in use any longer.

So, they are in turn generating a huge amount of waste and that too toxic waste, these batteries which store electricity they are very hazardous in nature and once discarded responsibly they are going to create a huge impact in the ecosystem. So, how we can save on through such impacts also, through this SPSS system is one of the beautiful examples to talk about here.

(Refer Slide Time: 35:53)

So, let us discuss the next topic which talks about a system design for sustainability, a new role for designer.

(Refer Slide Time: 36:00)

So, what is the system design we will discuss over here. Design approaches and skills from the sustainable system approach design the satisfaction of a particular demand, unit of satisfaction and all its related products and services, stakeholder configuration approach, design the interaction of the stakeholder of a particular satisfaction system and then system sustainability approach.

So, design such a stakeholder interaction this model that the economic regions continuously seek after both environmentally and socio-ethically beneficial new solutions. So, any product we have discussed earlier does not sets in isolation, every solution is meant for people, it is utilized by the people and there are number of stakeholders who are involved in fabrication or sourcing, then the power generation, then operations, in the uses and at the disposal.

So, all of these stakeholders if we combine them into one unit and if we design our product and the service system in such a way that it serves the system efficiently and if there is any need needed to improve the entire system, for that we can intervene at that stakeholder level or that unit level to improve the efficiency of that product and in turn we can improve the efficiency of the entire systems. So, that is where this system sustainability comes into the picture by intervening at one stakeholder, at one level, how we can improve the entire system around that product.

(Refer Slide Time: 37:44)

So, this is what it talks about. So good news in this area it is available as knowledge base and know-how methods and tools to design sustainable product service systems. Recently developed for SPSS applied to distributed economies.

(Refer Slide Time: 37:58)

But there are some challenges also, design and the offer of win-win sustainable product service systems is still very limited. So, we have seen some solutions which certain companies are offering in the market but they are very limited, very few in number. So,

the direct product selling approach is still has the major share, rather the SPSS almost has a negligible presence in the entire economic model, (())(38:29) society. So how this share can be improved is a matter of discussion now, how this efficiency can be brought in.

(Refer Slide Time: 38:37)

So, state of the art, given the great opportunities and responsibilities as well as the new knowledge base and know-how developer for the designers. Today few within the design community are equipped with a solid knowledge base and know how on design for sustainability. Today the design community as a whole is still more part of the problem than part of the solution.

So, how this can be improved is a matter of discussion, how you can adopt these strategies, stop these approaches while you are designing your projects, so this must get incorporated in your thinking, in your thought process for going about any project.

(Refer Slide Time: 39:18)

So, from here and onward we will discuss about certain strategies of sustainability design in our product design domain. So, one by one we will talk about product environmental effects and requirements, life cycle assessment, product life cycle design for life cycle and functional approach for strategic and guidelines approaches, methods and tools.

(Refer Slide Time: 39:41)

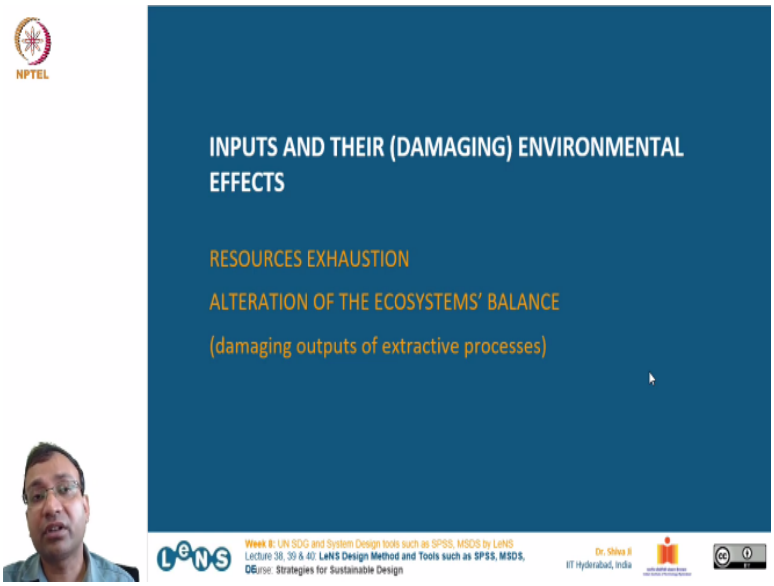
So, let us move on to the first one under this series, the sixth topic of discussion under this lecture. Product Environmental Effects and Requirements.

(Refer Slide Time: 39:51)

So, what are the environmental requirements? It is to design for minimizing products environmental impacts, environmental damaging effects, so the each environmental effect is based on a substances exchange between the nature and the environment and a process of a production and consumption system. So this is how the interaction of the material is happening, we are sourcing it from nature, we are processing it again we are throwing it back into the nature.

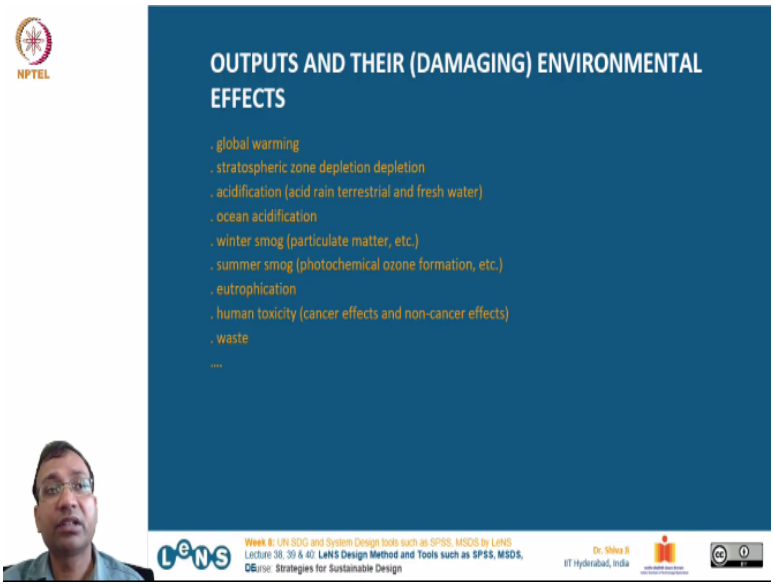
So, what kind of impacts are being generated that is very much evident, it is not going as desired. So, the input substance extraction from the environment. Output, substance emission in the environment, so these are the two things happening on, so we discussed in the life cycle stage, any life cycle of a product or any product consumes a resources in its input side and that excretes, it exhausts certain things as output, as effect of that processing and then maybe end up the life cycle stage of that product and all. So that becomes, forms the output part.

(Refer Slide Time: 41:02)



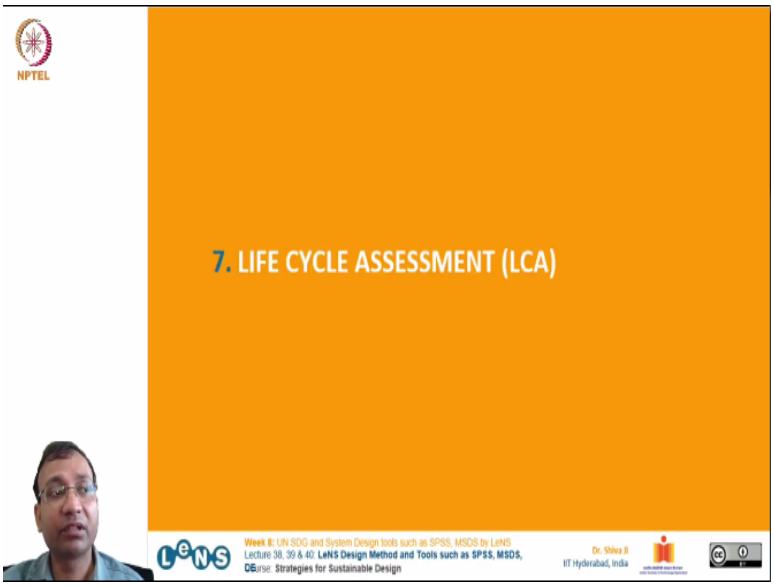
So, inputs and their damaging environmental effects. Well resource exhaustion first of all, first and foremost resources are getting depleted, alteration of the ecosystems balance and also the balance is getting disturbed, for example, if you are extracting water from the aquifers below the earth surface, those aquifers are getting dried and then the water table in the entire area is gradually have started going down and several cities, countries are facing this problem. In the recent times there is no groundwater available for several hundred feet in the ground. So, these are damaging outputs of extraction processes.

(Refer Slide Time: 41:49)



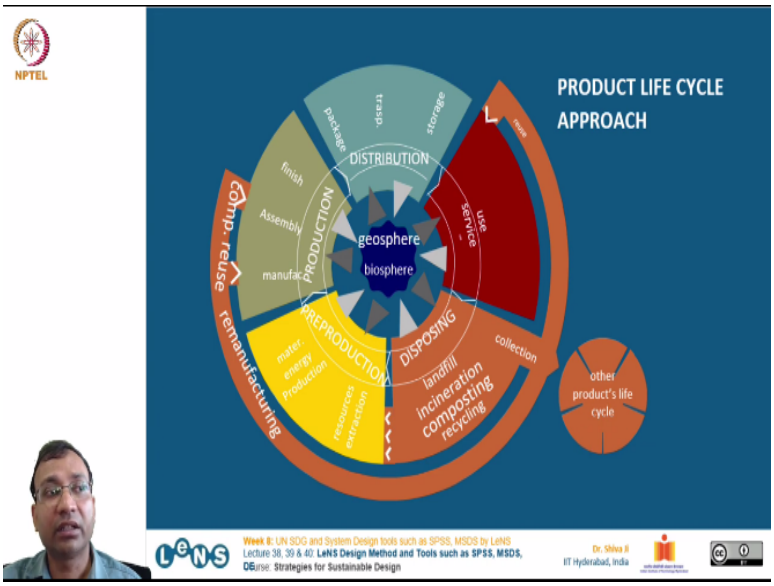
Outputs and their damaging environmental effects, well of course, we are all aware of global warming, stratospheric zone depletion is happening, acidification is happening, the acid rain terrestrial and fresh water disturbances are also happening in the fresh water, ocean acidification, winter smog, suspended particulate matter in the air, summer smog, photochemical ozone formation etcetera, eutrophication, human toxicity like carcinogens and other sorts of disease causing compounds are in the atmosphere these days and of course, the waste. So, these are some bad outputs.

(Refer Slide Time: 42:31)



Further, what is life cycle assessment. So, let us have a quick look, can we associate the environmental effects to a product, well how? So, the approach is product life cycle approach or functional unit. Evaluation method is like LCA, so we have discussed the LCA before, how we can apply to any given product and how we can assist the stakeholders in that entire system.

(Refer Slide Time: 42:58)



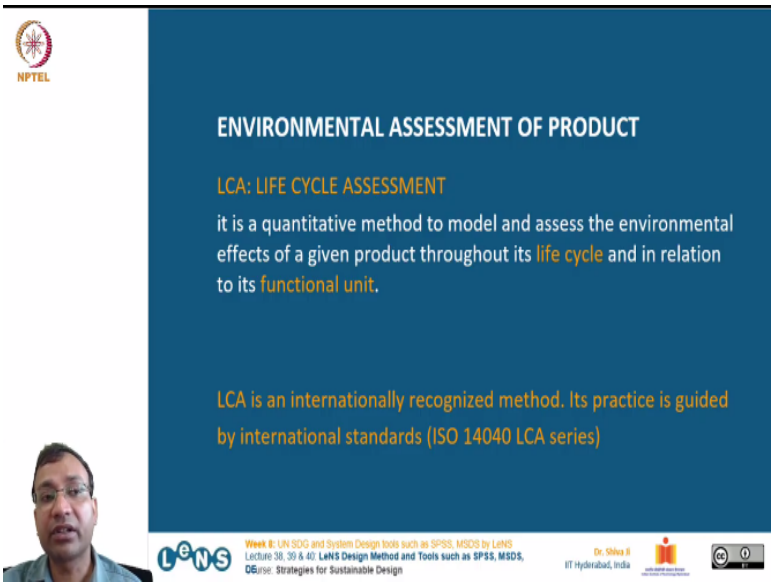
So, you can see over here this is a diagram of products life cycle, stages. Starting from if you see pre-production to production to distribution to use then again disposing. So from here we are starting this whole process and also in this segment, you see there is a resource extraction, material energy goes into producing it and then for production stage it goes for final manufacturing, assembly, finishing etcetera, and then again is further distribution, packaging, transportation, storage.

The uses part of it, the consumption part of it, then it goes for collection once the life expected, life expectancy is over, once the usage is completed and fulfilled then it goes for again recycling, reusing and etcetera or maybe ends up in the landfill. So this is where this disposing approach comes, so this is how it works normally.

(Refer Slide Time: 44:08)

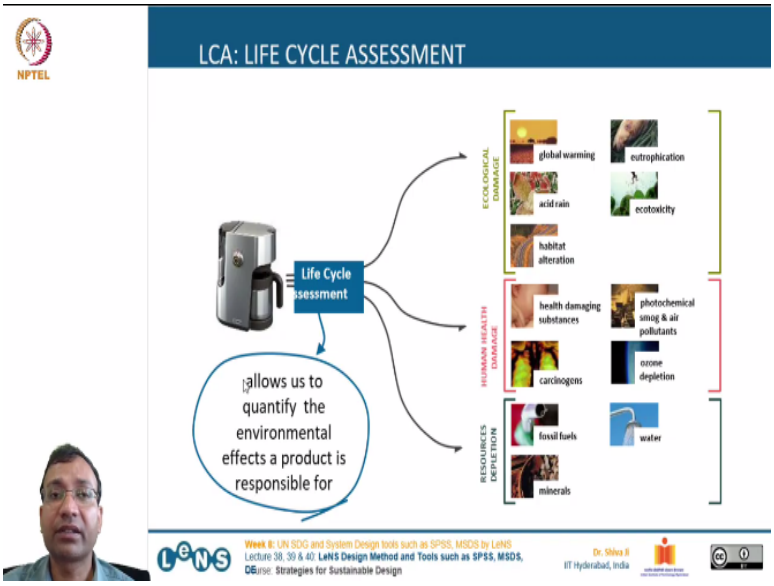
So, what is functional unit? Well functionality is not the product to be designed or assembled or assessed, but the whole of the process is associated with the fulfillment of given function. So, the functional unit is a quantified performance of the product that is being assessed to use as a reference unit within an environmental impact assessment of all its life cycle stages. So, remember, we spoke of SPSS, so this is related with that SPSS, we are talking about the functional unit of product in terms of fulfilling the service of it.

(Refer Slide Time: 44:42)



So, what is a life cycle assessment? Well, it is a quantitative method to model and assess the environmental effects of a given product throughout its life cycle and in relation to its a functional unit. So, LCA is an internationally recognized method, its practice is guided by international standards ISO 14040 LCA series.

(Refer Slide Time: 45:03)

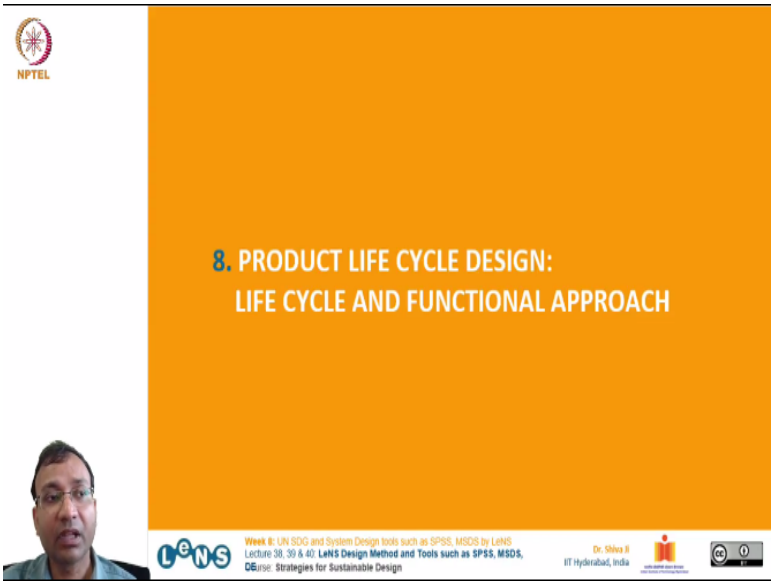


So, for example, it is given over here life cycle assessment of coffee maker, well it allows us to quantify the environmental effects a product is responsible for, so you see on these

three leg assessments over here, what are the possible damages, impacts and after effects caused by simple product such as a coffee maker. So, the ecological damages, global warming, eutrophication, acid rains, echo toxicity, habitat alteration and the human health damage is part, so health damaging substances, photochemical smog and air pollutants, carcinogens, ozone depletion on the resource depletion part, it is causing consumption of fossil fuels, water, minerals and several other things.

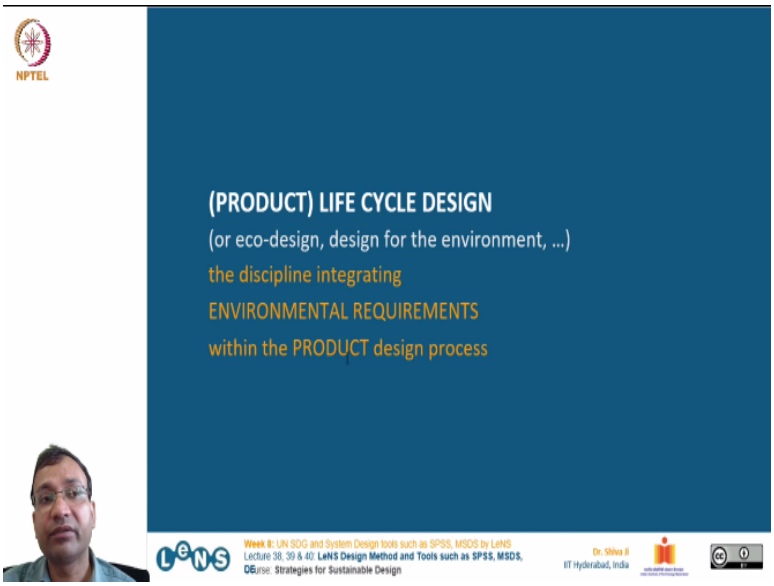
So, this is how we can, further we can take help some software which are recommended for this life cycle analysis and we can carry out an in-depth analysis of how the components of this unique product are sourced from how much energy invested, how much of material is invested and how much of energy is going to consume in its overall life cycle, in its operation phase and what are the kind of after effects at the end of its life cycle.

(Refer Slide Time: 46:34)



Further, the eighth topic of discussion, product life cycle design, life cycle and functional approach.

(Refer Slide Time: 46:40)



So, here we will talk about this life cycle design which can be called as eco design also, a design for the environment which although synonyms. So, the disciplines integrating environmental requirements within the product design process.

(Refer Slide Time: 46:57)

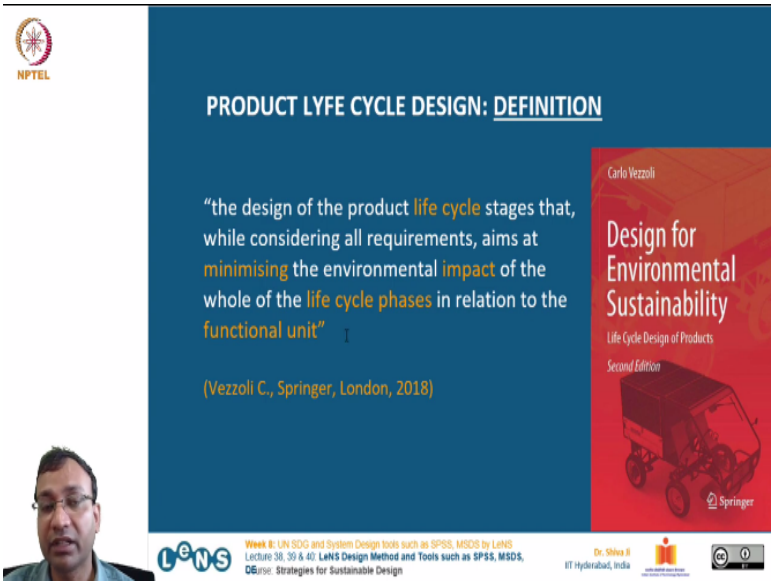
So, here if you see the approach an extended design horizon, from product design to the design of the product life cycle stage. So, this is what we focusing on, we are not just designing the product we are designing the life cycle of that product. So, the design

reference from product design to the products function design, so we have discussed in the SPSS that is what this approach of this SPSS is further bifurcated and made into actionable points.

For example, if you are going to design product for example, a milk packaging unit, then how we can do it, how we can think of it as not an end product for example, currently whenever we buy a packet of milk, we end up with that packaging also, so how can we go for a service based solution, product service based solution, so that our objective, our requirement is to receive the milk, not the packaging part. So, how we can receive the milk as well as still at the same time we can manage to give the packaging back to the manufacturer or the company and there it can be again taken care for recycling or reusing.

So, this is where what we are talking about designing for life cycle stages, designing for a products functional design. The environmental design objective minimizes the environmental impact of the whole of the phases in relation to the functional units, well that is the overall purpose of this exercise.

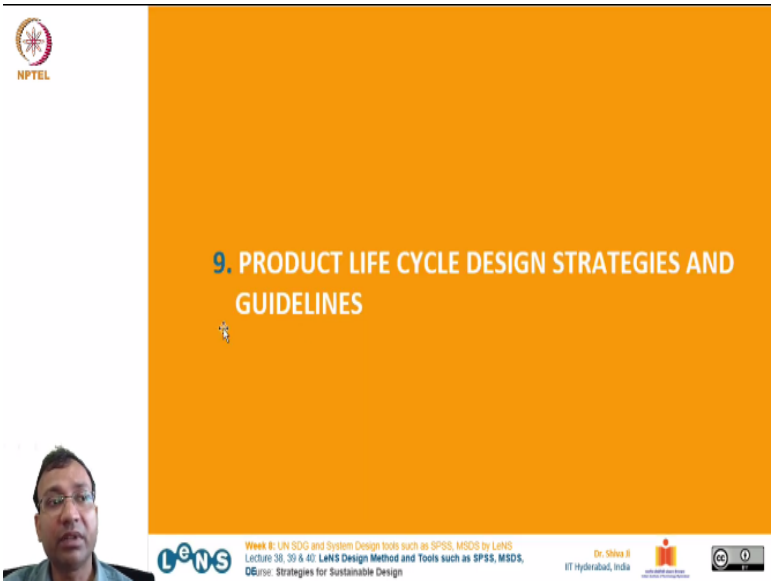
(Refer Slide Time: 48:32)



So, some papers and literatures are given under in this book, maybe you can refer it in your free time. The design of the product life cycle stage is that while considering all

requirements aims at minimizing the environmental impact of the whole of the life cycle phases in relation to the functional unit, this is what it means.

(Refer Slide Time: 48:49)



Further, in the net next topic we will discuss about product life cycle design strategies and guidelines. So, what are the strategies we can apply in our designs? So here we will see some examples in detail and we will discuss about some strategies in detail.

(Refer Slide Time: 49:07)

So low cost, low life cycle impact designed, so on the environmental studies minimizing material consumption, minimizing energy consumption, optimizing resource renewability and biocompatibility, minimizing resources toxicity and harmfulness, product lifespan of optimization, extending the lifespan of the materials and design for disassembly. Well, these strategies we have discussed in detail earlier, we will see in more detail in these coming slides.

(Refer Slide Time: 49:40)

So for example, if you see this electric guitar as product, so what is the approach do you see compared to these figures over here, these two pictures over here. Well of course, minimizing the material content of that product, so this is the approach adopted in this equipment, well it is done for the aesthetical purpose also but at the same time it solves the problem of resource minimization also, because for an electric guitar you do not need this volume to resonate and create that sound effect with this box generates while playing the guitar.

So, how by removing this material over here we can minimize the consumption of this wood because these guitars are made naturally by using wood, so how this kind of design can minimize the consumption of the material. So, dematerializing the product are some of its components, so that is the objective in one of the strategies which we are talking about here, about material minimization, so this is one example over here.

(Refer Slide Time: 50:56)

Further, in the discussion part, minimizing material consumption, well how? So, minimizing material content of a product, dematerialize the product are some of its components, digitalize the product or some of its components, miniaturize maybe reduce in the scale and the proportions, avoid over size dimensions, reduce thicknesses, apply ribbed structures to increase structural stiffness, avoid extra components with little functionality.

So, these seem to be very common sensical approach and ideas, but this is very important for us to consider while we are on the drawing stage, while we are on the conceptualizing state for any product design. Further, minimizing scraps and discards, select processes that reduce scraps and discarded material during the production, engage simulation systems to optimize transformation processes.

Further, minimize or avoid packaging, avoid packaging first of all, apply materials only where absolutely necessary otherwise do not use packaging materials, design the package to be part or to become the part of the product, so that the moment the product is delivered to the user, the packaging usually gets discarded immediately, so the lifespan of packaging material is comparatively very short compared to the product, so how this disparity can be minimized, so that is the objective over here.

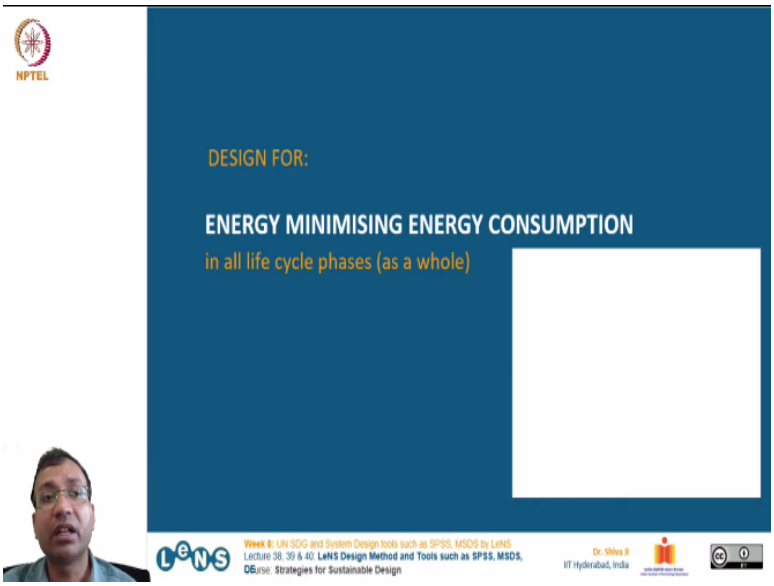
Further, this strategy of minimizing material consumption during uses, so design for more efficient consumption of operational materials, design for more efficient supply of raw materials, design for more efficient use of maintenance materials, design systems for consumption of passive materials which does not utilizes energy extensively, design for cascading recycling systems, facilitate the user to reduce material consumption, set the product's default state at minimal materials consumption.

So, anyways for example, we have these automobiles, so they keep consuming fuel for their entire lifespan, so how this efficiency of this fuel consumption can be increased, so this is what we are talking about over here, minimizing the materials consumption during the usage period. Further, in the next strategy adopt flexible material consumption systems during uses, so engage digital support systems with dynamic configuration, design a dynamic material consumption for different operational stages, engage sensors to adjust materials consumption according to differentiated operational stages, reduce resource consumption in the product's default state. So, this is how we can go for flexible material consumption system also during the operations stage.

Finally, this strategy of minimizing material consumption during the product development phase, so minimizing the consumption of stationary goods and their packaging, engaging digital tool designing, modeling and prototyping, engaging digital tools for documentation, communication and presentation. So, the kind of stuff we do in our studios and classroom, so how we can minimize on the stationary and how we can minimize on the other support materials and how we can go as much as possible digital. So, for designing also we can go for digital sketching, digital 3D modeling, digital prototyping, digital simulation and testing and then finally if need is there then we can go for the final material-based prototyping on our experiments.

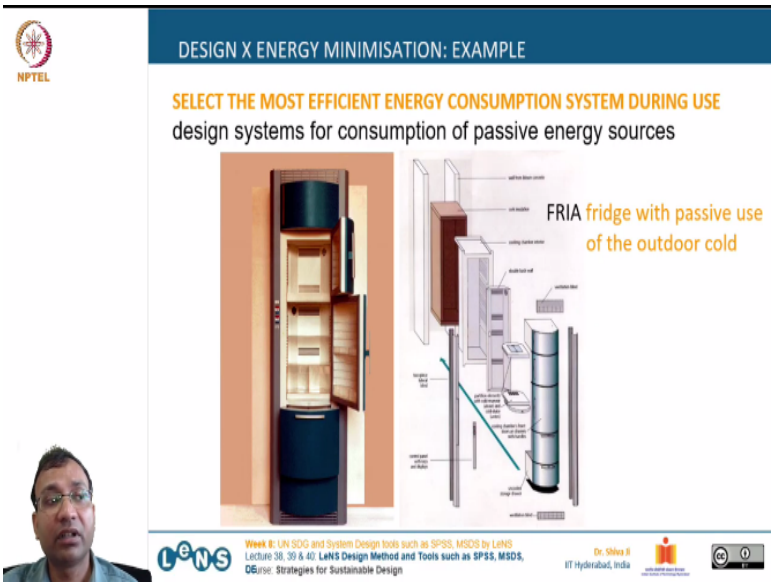
So, in turn we will end up reducing the materials required for product development phase, so see the kind of potential this exercise has is really immense and it is really eye opening for you as designer, you should employ such as strategies in your design exercises.

(Refer Slide Time: 54:55)



Further, we will see for energy minimizing, energy consumption in the later products.

(Refer Slide Time: 55:02)



So, we have this case example over here. So, the objective, the strategy is designed for energy minimization, so the example of select the most efficient energy consumption system during uses. So, design system for consumption of passive energy sources, so it is a simple fridge, the refrigerator given over here, so this FRIA fridge with passive use of the outdoor cold, so how this fridge uses the outside cold which is normally there in the

colder countries and reduces the energy demand. So, this is why this example is given over here, that it utilizes the outside chilly weather to create this cold atmosphere inside this fridge.

(Refer Slide Time: 55:53)

Further, so what are the strategies we can go for considering while we are thinking about minimizing energy consumption. So, there are 5 strategies given over here, we will discuss one by one. Minimize energy consumption during pre-production and production stages, so what are the smaller, finer strategies which can be adopted for this? select materials with low energy intensity, of course, so the material intensity of the product should be lesser, we have discussed alloys and polymers these are really energy intensive material, they consume a lot of power, a lot of energy in their production stages.

So, if it is possible to go for other alternative materials for such energy intensive material, we must go for those. Select processing technologies with the lowest energy consumption possible, this consumption pattern we should go for energy efficient machinery and use heat emitted in certain processes for preheating other process floor, so the energy wasted in some process can be utilized for the other process, so this kind of approach, engage the pump and motor speed regulators with dynamic configuration, you may have seen some examples where the bicycles are fitted with the dynamos, so the kinetic energy of

that wheel can be utilized by the dynamo to create, to generate power needed to light the bulb which is installed in that cycle.

So, that is what we are talking about over here, the energy wasted in some industrial process, some process can be utilized for the other process. Further, equip the machinery with intelligent power of utilities, so that there is no power wasted once the machine is not in the use, optimize the overall dimensions of the engine and facilitate engine maintenance, define accurately the tolerance parameters, how to optimize the volumes of required real estate, optimize stock taking systems, optimize transportation systems and scale down the weight and dimensions of all transportable materials and semi products, engage efficient general heating in illumination and ventilation in the buildings.

So, these are several methods, several finer strategies through which we can go on energy consumption reduction in the pre-production and production stages. Further, towards the next stage, minimizing energy consumption during transportation and storage, so design compact products with high storage density, so that every square inch, every volume inch is used for transportation and the efficient transportation of this stuff, so that we can maximize the usage after fuel consumed, design concentrated products, equip products with the on-site assembly, scale down the product weight, scale down the packaging weight, decentralize activities to reduce transportation volumes, select local material and energy sources.

So, these could be strategies for minimizing energy consumption in transportation and user stage. Further, the third strategy, select the most efficient energy consumption system during the use, so while using we must use energy saving methods and strategies, so design products for collective use, design for energy efficient operational stages, design for energy efficient maintenance, design systems for consumption of passive energy sources, engage highly efficient energy conversion systems, design or engage highly efficient engines, design or engage highly efficient power transmission, use highly caulked materials and technical components, design for localized energy supply, scale down the weight of transportation goods, design energy recovery system, design energy saving system.

So, these are strategies needed for reducing energy efficiency, reducing energy consumption, sorry, in the usage period. Further we have this fourth strategy, enable a variable consumption of energy to follow demand fluctuations, so engage digital dynamic support system, design dynamic energy consumption system for differentiated operational stages, engage sensors to adjust the consumption during the differentiation operational stages, equip machinery with intelligent power off utilities, program product default state at minimal energy consumption.

And finally, we have this fifth strategy of minimizing energy consumption during product development stage, so engaging efficient workplace heating, illumination, ventilation systems, engaging digital tools for communicating with the remote working sites. So, these are the very exhaustive strategies, a list of the strategies you can see which are designed specifically, which are laid out here specifically for various life stages of a product and how and where I think we should make this intervention to minimize the impact and minimizing the energy consumption is the actual idea being discussed over here.

(Refer Slide Time: 61:09)

So, the next strategy over here is designed for minimizing resources toxicity and harmfulness. So, in an overall life cycle stages of product, so minimizing material toxicity and harmfulness, minimizing energy toxicity and harmfulness.

(Refer Slide Time: 61:24)

So let us see one example over here. We have this example of this microfiber rags for home cleaning. So, it says select non-toxic or harmful or harmless material, design products that do not consume toxic and harmful materials, rags for home cleaning in microfiber no need for detergents. So, if we see this fiber over here, so this has capacity to wipe out the dirt and the kind of waste material which we want to wipe our utensils and surfaces cleaning in kitchen.

So, this material does not require detergents in general, so how the quality of the material itself can be made useful for creating the harmless materials, because detergents and other cleaning agents they are somehow carry this toxicity, some amount of toxicity in them.

(Refer Slide Time: 62:27)

Further, environmental impacts of materials, so depends on material specific characteristics, characteristics given to product. So, the ranking from the best to the worst, so this could be misleading, so an in-depth analysis is needed.

(Refer Slide Time: 62:45)

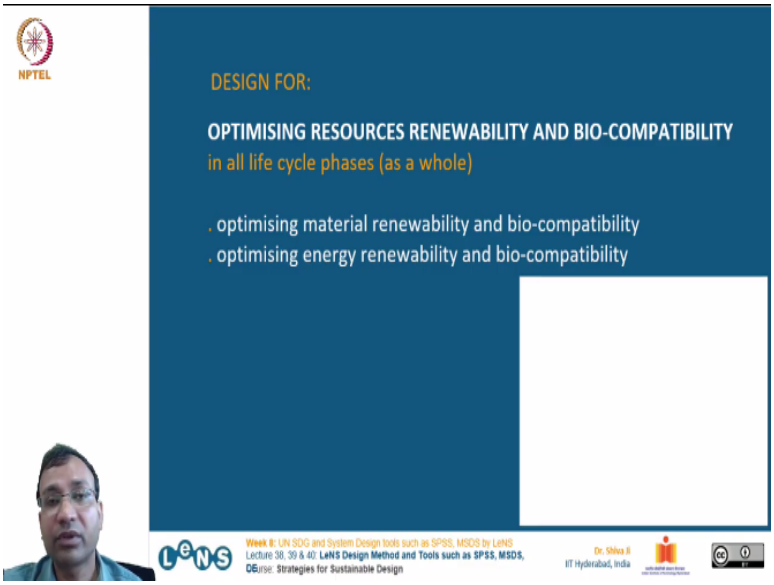
So, let us see what are the strategies for such situations, so minimizing the resources toxicity and harmfulness. So, under that there are two major strategies, we will see one by one. So select non-toxin, harmless materials, avoid toxic or harmful materials for product

components, minimize the hazards of toxic and harmful materials, avoid materials that emit toxic or harmful substances during pre-production, avoid additives that emit toxins or harmful substances such as (())(63:13) we have discussed, the paints and other finishing materials used in the furniture and interior or surfaces.

Avoid technologies that process toxic and harmful materials, avoid toxic or harmful surface treatments, avoid products that do not consume toxic and harmful materials, avoid materials that emit toxic or harmful substances during uses, avoid materials that emit toxic or harmful substances during disposal. So, based on the life cycle stages we can go for each and every stage and we can rework, so that the overall minimization in toxicity can be addressed and all those levels.

Finally, select non-toxic and harmless energy resources, select energy resources that reduce the dangerous emissions during production stages, select energy resources that reduce dangerous emissions during distribution stages, during usage stage and during the resource that reduces dangerous residues and toxic and harmful waste also at the end of its life cycle stage. So, these are the stage approaches which could be utilized for reducing the toxicity and reducing the waste.

(Refer Slide Time: 64:33)



Finally, we have this design for optimizing resources renewability and biocompatibility. So, optimizing material renewability and biocompatibility, optimizing energy renewability and biocompatibility, so we are seeing there are always two components to any such analysis, one is on the material and resource's part and second is on the energy part. So, we have to keep focusing on both of these components.

(Refer Slide Time: 65:00)

Let us see one example over here. So, for design for renewability and biocompatibility, select renewable and biocompatible energy resources, use renewable energy resources. So, this is solar lawn mower because this grass cutting machines usually what we use in our homes they are either driven by a hydrocarbon or maybe they use electricity from the grid.

So, is it possible that we can go for a solution so that this keeps on moving this grass on a regular interval and utilizes only solar energy because most of these times this operates in the daytime and it remains outside, so that the design can be facilitated in such a way that it can be designed in a weather proof manner, which remains outside which takes care of its own, recharging it takes care of the mowing of this lawn. So, this is one very simple solution what we are talking about over here.

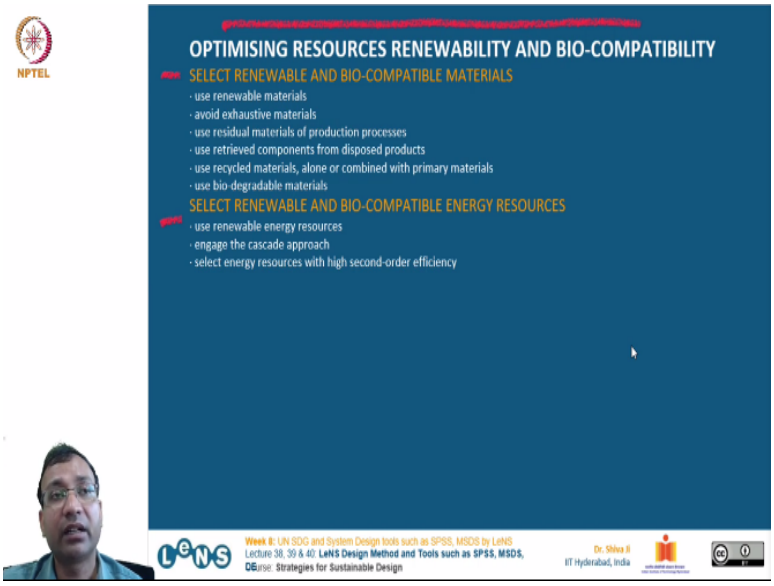
(Refer Slide Time: 66:08)

Another if you see, select renewable and biocompatible materials, use biodegradable materials for compostable products pots for plants and made of corn starch biodegradable polymer by Novamont. So, this is one particular company and particular product we are talking about over here, so plastic has impregnated in most of our products these days, so if it is possible why cannot we use a starch based biodegradable polymers which at the end of their life cycle they can go without leaving any toxic residues in the ecosystem.

(Refer Slide Time: 66:47)

So, we are talking about here resource renewability which depends on re-growing specific speed, extraction frequency, so a resource is renewable if a context related, if anthropic consumption rate is lesser than the natural re-growing rate. So, the nature has this replenishing capacity for natural elements, but there is always a threshold, so our consumption, we discussed in one of the previous lectures, the bio capacity and the overall footprint of the growth and development, so that should not exceed the bio capacity. Well, most of the products in today's time doing that, so how this consumption rate can be lowered compared to the natural re-growing rate and natural replenishment rate, so that is the thing what we are talking about over here.

(Refer Slide Time: 67:45)

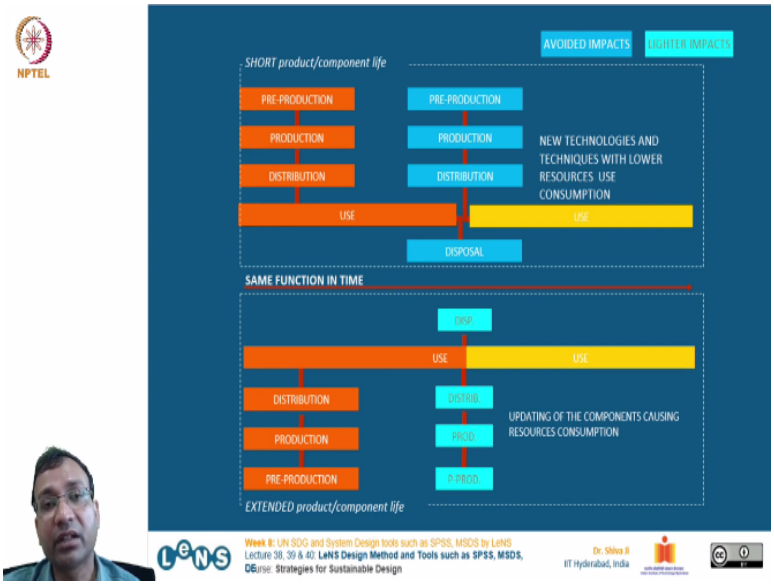


So, under this renewability and biocompatibility discussion, we have two major strategies over here to talk about, select renewable and biocompatible materials and select renewable and biocompatible energy sources. So, in this one use renewable materials, avoid exhaustive materials, use residual materials of production processes, use retrieved components from disposed products, use recycle materials alone or combined with primary materials, use biodegradable materials. Finally, in this strategy we have use renewable energy resources, engage the cascade approach, select energy resources with high second order efficiency.

(Refer Slide Time: 68:26)

Further, moving on product lifespan optimization, how the longevity can be extended, how the product can be made serviceable for a longer period of time, minimizing the need of additional or the second unit of the same material. So design for product component lifespan extension, design for component use intensification.

(Refer Slide Time: 68:47)



So, we will see in this illustration over here, so if you see further short product and component life from pre-production to production to distribution and uses, how this

effect can enhance the longevity of any product and system. So, if you see on this parameter new technologies and techniques with the lower resources use consumption. So, this is at the end of it they go for the disposal and the same function in time if you see so the disposal and the usage come, the disposal is relatively smaller, the uses is longer than comes to distribution production and pre-production so it gets inverted.

So, updating after component causing resource consumption, so here if we see the time span required for product to function and gets at the end of its life cycle that can be extended, so that the need for another item, this another same product can be minimized.

(Refer Slide Time: 69:57)

For example, if you see over here this is a beautiful example taken from a home-based furniture, see how the adaptability is utilized over here as one of the strategic points and the products life cycle, the product, the longevity of product is extended for a longer period of time. So, you see the child over here, this child has grown into this girl and now further in her young age, so the same set of these components of this product they are designed in such a way that they can be changed by the combination of this they can be changed into another set of products, so this has turned into a table over here and another a study table over here or a period of time.

So, design multifunctional and reconfigurable products to facilitate their adaptability for changing cultural and physical characteristics. So if you see this furniture, it can be transformed from changing table to table for kids to a desk for young people, so this is how the same product by rearranging its component in a certain way, it gets additional usage, so that is an extended life span of a product.

(Refer Slide Time: 71:20)

So, how this lifespan optimization can be done, so there are some strategies listed down over here that designing appropriate lifespan, so design durable components, choosing materials and appropriate ways to preserve performances in relationship with the forcing uses condition, design components with co extensive lifespan, design lifespan of replaceable components according to scheduled duration, select durable materials according to the product performance and lifespan, avoid selecting durable materials for temporary products or component.

Further, we have strategy of design for reliability, so reduce overall number of components so that the system remains simpler, simplify the product, eliminate weak liaison, eliminate the weaker components, further the third strategy over here is facilitate upgrading and adaptability, how you can do, there are some points given over here enable and facilitate software upgrade, enable and facilitate hardware upgrade, design modular and dynamically configured products to facilitate their adaptability for changing

environments, design multifunctional and dynamically configured products to facilitate their adaptability for changing cultural and physical individual backgrounds.

Design products that can be upgraded and adapted on site, design complementary tools and documentation for product upgrade and upgradation, so at the end of the normal lifespan of that product there should be some support so that that product can be upgraded into a new product, knowledge source is such these complementary tools and documentation must be given along with that product at the time of the purchase.

Finally, we have this strategy this point of facilitate maintenance, so simplify access and disassembly to components to be maintained, avoid narrow slits and holes to facilitate excess for cleaning, pre-arrange and facilitate the substitution of short light components, equip the product with easily usable tools for maintenance, equip products with diagnostic and auto diagnostic systems for maintainable components, design products for easy on-site maintenance, enabling parts cleaning and or replacements, design complementary maintenance tools and documentation, design products that need less maintenance. Of course, by designing products which require a lesser maintenance and repairing we can optimize on the overall efficiency of that product and overall longevity of that product.

(Refer Slide Time: 73:48)

Further, in this we have four more strategies over here facilitate repairs, facilitate reuse, facilitate remanufacturing, intensify uses. So arrange and facilitate disassembly and reattachment of easily damageable components, design components according to standards so that they can fit from one product to another, equip products with automatic damaged diagnostic systems, design products first facilitated on-site repairs so that they need not be taken to the service centers, design complementary repair tools materials and documentation.

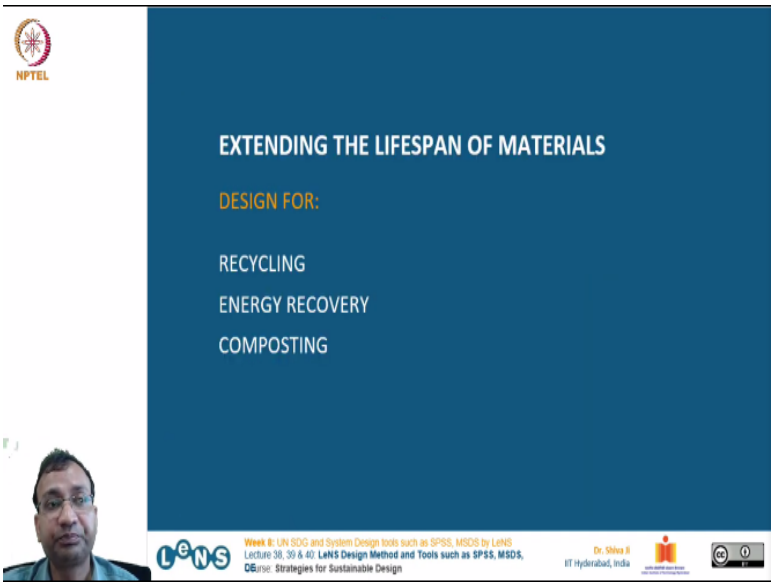
On the strategy of facilitating reuse, increase the resistance of easily damaged and expandable components arrange, and facilitate access and removal of retrievable components, design modular and replaceable components, design components according to standards to facilitate replacement, design reusable auxiliary parts, design refilling and reusable packaging, design products for secondary use.

Further, we have this strategy of facilitate and re-manufacturing, so design and facilitate removal and substitution of easily expandable components, design structural parts that can be easily separated from external visible ones, provide easier access to components to be remanufactured, calculate accurate tolerance parameters for easily expandable connections, design for excessive use of material for easily deteriorating surfaces.

So, this is how we can allow the product to be remanufactured into some more other product or some other design, so it is allowing the preserving finishing away preserving the structure and integrity of it, so that these parts as a whole or as a component can go into utilize as remanufacturing like an item.

Further, we have a intensify uses a strategy, so a design product service for shared use so that a number of people can make use of the same product, so that they need not buy it independently so many times, design multifunctional products with common substitutable components, design products with integrated functions, designed for products or product part on demand and design for products or products parts on availability. So, these are some actionable points which we saw under the strategies for lifespan optimization, so that the product can be used for extended period of time, so this is how this can be facilitated.

(Refer Slide Time: 76:13)



So, design for extension of the lifespan, so design for recycling, design for energy recovery, design for even composting.

(Refer Slide Time: 76:23)

Further, in this topic we will discuss about materials recyclability, combustion, composting etcetera, it depends on a specific material characteristic, performance recovery and cost of processes. Products architecture, recycling phases, collection,

transportation, separation, disassembly or crushing identification, cleaning, secondary raw materials production etcetera.

(Refer Slide Time: 76:45)

Let us see some strategies from this topic. So, for extending the lifespan of the material, so there are four strategies listed down over here adapt the cascade approach, select material with most efficient recycling technologies, facilitate end-of-life collection and transportation and material identification. So for these the actionable points are arrange and facilitate recycling of materials in components with lower mechanical requirements, arrange and facilitate recycling of materials in components and lower aesthetical requirements, arrange and facilitate energy recovery from materials throughout combustion.

Well further, we have selected materials that easily recover its original performance characteristics after recycling, so that it can be reused effectively and after the recycling avoid composite materials or when necessary, choose easily recyclable ones, the one point I have been talking several times, we must go for simpler materials which are easy to dismantle or bifurcate at the end of their life cycle otherwise they will become extremely difficult to reuse them into some more ways.

Engage geometrical solutions ribbing to increase polymer stiffness instead of reinforcing fiber, prefer thermoplastic polymers to thermo setting, prefer a heat proof thermoplastic polymers to fire proof additives, in a design considering the secondary use of the materials once recycled, the next we can see this strategy of facilitate end of life collection and transportation.

So, this is one of the important strategies over here design in compliance with the product retrieval system so that it can be retrieved, minimize overall weight, minimize cluttering and improve stackability of discarded products so that they can be brought back in a efficient way, design for the compressibility of discarded products, so that again optimizing on the space while you are transporting and packaging.

Provide the user with information about the disposing modalities of the product or its parts, lastly we have this strategy of material, identification codify different materials to facilitate their identification, provide additional information about the materials age, number of times recycled in the past and additives used, indicate the existence of the toxic or harmful materials, use a standardized materials identification system, arrange codifications in easily visible places and avoid codifying after components production stages.

So, these are standard procedures but must follow while packaging and labeling their products, so that this set of information are easily available on product package, so this will become very handy at the end of its life cycle stage, so that if it is being taken for recyclability or reusability or re-manufacturability, so how and what are the components that can be used in those ways is can be easily deciphered to these codes and this information.

(Refer Slide Time: 79:49)

So, I have taken some examples over here for you to understand facilitating end of life collection and transportation, design for compressibility of discarded product, so this is one of the actionable points we discussed under this strategy, so you see this is a particular brand of these water bottles they designed their bottles in such a way, so that after they are discarded they can be easily compressed in a smaller volume, so it becomes very easy and optimal for the recycler to collect these discarded water bottles and take it to the facility.

(Refer Slide Time: 80:27)

Further, we have this example over here minimizing the number of different incompatible materials, so use only one material per product or per sub assembly, so here if you see this Hermann Miller again is back with one of the very good examples, so the chair's back made with one material only, so the entire this back unit does not utilize combination of different materials which is very difficult to segregate or dismantle them at the end of their life cycle, so this whole unit of this back can be again directly taken for recycling and dismantling because this is a one, a single material altogether. So, this is the some examples we saw in the real life. So, how such kind of intentions can help in designing products with these thought processes.

(Refer Slide Time: 81:19)

Further, we will see extending the lifespan of the product over here, there are some more points given, some strategies are given over here which will facilitate extending the life cycle, lifespan of product. So, the strategies listed over here are minimize the number of different incompatible materials, facilitate cleaning, facilitate composting, facilitate combustion finally.

So, integrate functions to reduce the overall number of materials and components, mono material strategy only one material per product or product per sub assembly, use only one material but process in sandwich structure and use compatible materials that could be recycled together within the product or sub assembly, for joining use the same or compatible materials as in components to be joined, so we saw in the previous example of this Hermann Miller chair, so how the same material is used in the different components of the back, so minimizing the issue in dismantling and taking it off.

For a strategy of facilitating cleaning avoid unnecessary coating procedures, avoid irremovable coating materials which cannot be taken out, facilitate removal of contaminants, use coating procedures that comply with coating the coated materials, avoid this is or choose ones that comply with the materials to be recycled, prefer the dyeing of internal polymers rather than the surface painting, avoid using additional materials for making codification, mark and codify materials during molding itself so that

there is no need of painting and putting up these coats later on, mark and codify materials during molding and codify polymers using a laser, so that there is no additional ink or such kind of complex pigments needed to put on those codes.

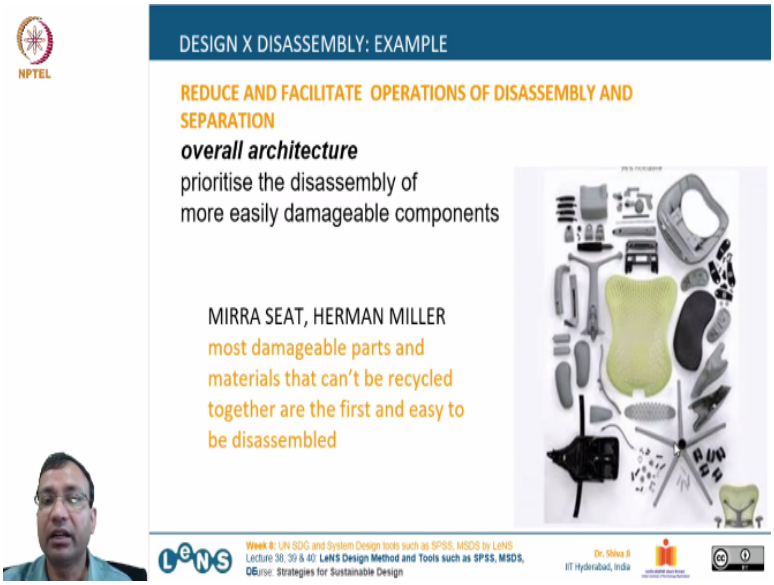
Further, we have this strategy of facilitating composting, so select materials that degrade in the expected end of life environment, avoid combining non-degradable materials with products that are going to be composted, facilitate the separation of non-degradable materials and finally we have this strategy of facilitating combustion, so select high energy materials for products that are going to be incinerated, avoid materials that emit dangerous substances during incineration and avoid additives that emit dangerous substances during incineration, facilitate the separation of materials that would compromise the efficiency of combustion with low energy.

So, these are points we saw over here, even the compounds such as adhesives are very important to be chosen judiciously, so that at the end of their life cycle they are not going to create a mess while even if we are going for incinerating or combusting them. So, such is level of sensitivity that is needed to address these critical issues.

(Refer Slide Time: 84:12)

Finally, a design for disassembly, so of parts, components, product life optimization, of materials like material life extension.

(Refer Slide Time: 84:22)



So, one of the beautiful examples taken over here for design for disassembly is this chair, so if you see reduce and facilitate operations of disassembly and separation, overall architecture, prioritize the disassembly of more easily damageable components. So, this is a MIRRA seat from Hermann Miller, so the most damageable parts and materials that cannot be recycled together are the first and easy to be dismantled first, so you see all the components of this chair are laid out over here, so they are easy to dismantle, disassemble and accordingly they can recycle these parts or reuse these parts depending upon their condition.

(Refer Slide Time: 85:03)

So, further we have for under the last this setup like a strategy is designed for disassembly. So, we have three strategies listed down over here reduce and facilitate operations of disassembly and separation overall architecture and shape of components and parts, shape and accessibility of joints.

So, prioritize the disassembly of toxic and dangerous components or the materials, prioritize the disassembly of components and materials with higher economic value, prioritize the disassembly of more easily damageable components, prioritize the disassembly of the parts that are more subject to technological or aesthetic obsolescence, engage modular structures and divide the product into easy separable and manipulable sub assemblies and minimize overall dimensions of the product, minimize hierarchically dependent connections between the components and minimize different directions in this disassembly root of components and materials, increase the linearity of the disassembly route, engage a sandwich system of disassembly with central joining elements.

So, these could be actionable points to facilitate responsible disassembly and separability. Finally, with the strategy of shape of components and parts, so the actionable points are avoid a difficult to handle components, avoid asymmetrical components unless required, design leading surfaces and grabbing features in compliance with the standards, arrange

leaning surfaces around the product center of gravity, design for easy centering on the component base.

Finally, shape and accessibility of joints, avoid joining systems that require simultaneous interventions for opening, minimize the overall number of fasteners and minimize the overall number of different fastener types that demand different tools, avoid difficult to handle fastness and design as a accessible and recognizable entrances for dismantling, the design accessible and controllable dismantling points. So they seem very who cares for kind of kind of a points but they are very important while product goes for a disassembly.

So, you can take maybe a raw or maybe a discard piece of furniture or any product in your house and you try dismantling it and see how you experience for disassembly, so just imagine yourself as a recycler person who will be dismantling that unit by hand in some facility, so how well, how easy that product is for you to open it up, so that you can divide it into itself number of components, you can segregate and send them for responsible recycling, so you will understand how important it is to consider these points for design for disassembly.

(Refer Slide Time: 87:45)

Product life cycle design strategies, so the priorities, do some strategies have greater priorities than others? For every product some strategies have greater priorities than

others, it is important to be able to properly identify environmental design priorities and LCA tools can be used to support this task. Well, we have seen the number of strategies and number of actionable points, which one to employ, which one to apply in which product, so that you also need to understand, so that is what we are talking about here, which is the greater priority, you must analyze before going to choose the relevant strategy for carrying out those tasks.

So, it is very important to understand for example, a vehicle utilizes, we have seen in the LCA analysis, so this is where LCA analysis become very useful to understand the scenario of a product, how it is performing over different life stages. So, for example, an automobile consumes huge amount of fuel over its entire life cycle, so the priority should be to minimize the fuel consumption and for example, a chair we have seen in this lecture, a chair is used in a house or in an office for definite purpose, the purpose is very, very fixed and clear.

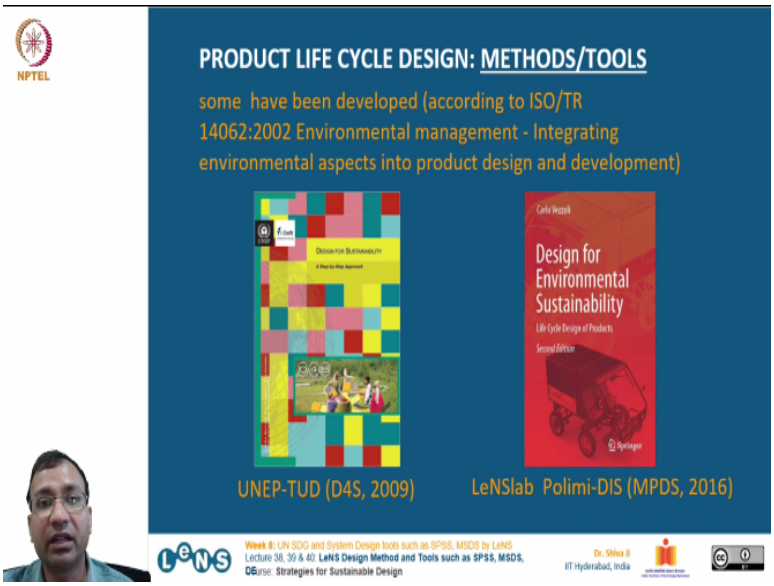
So is it possible that we can extend the lifespan of it, so that we can keep on using, using, using for a longer period of time, because a chair need not be changed just for the sake of it or just for going for other silly reason, so that I want to just change my interiors, or I want to redo my interior, so things like that?

So, these are very bad habits as far as the habits and behaviors are concerned and we have seen in the consumerism chapter how such kind of attitude and behaviors are causing damages to the ecosystem. So, we must control for starting from the behaviors and habits to the operations and we must learn how to priorities and what are the priorities which must take care of while designing a life cycle or the functional unit of our product.

(Refer Slide Time: 89:57)

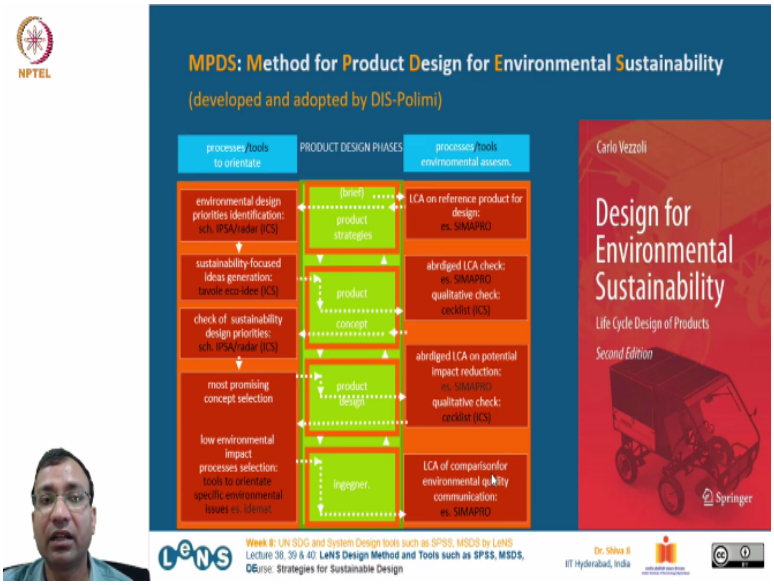
With this we are almost at the end of this lecture, so this is the last topic of discussion over here, so about the product life cycle design methods and tools. So, in this we will see there are some tools and methods and techniques given under the banner of this organization, the logo you can see at the left bottom side over here LeNS, this is learning network for sustainability, you can search this website the address was given in the beginning, I will give it again at the end of this presentation and you can go to that website, you can register yourself as a student or as a academician or professional or researcher and you will be able to download these tools and techniques and methods for applying in your design projects.

(Refer Slide Time: 90:41)



So, you can go for referring these books, this book is available freely to download and also these are some of these books are developed as a common open-source material for knowledge dissipation around SPSS, MSDS and DE techniques.

(Refer Slide Time: 91:04)



Further, you can see MSDS method for product design for environmental sustainability, so this table you can see over here, so this diagram gives us a flow diagram how to take a product design in phases, so you can see process and tools to orientate are given in this

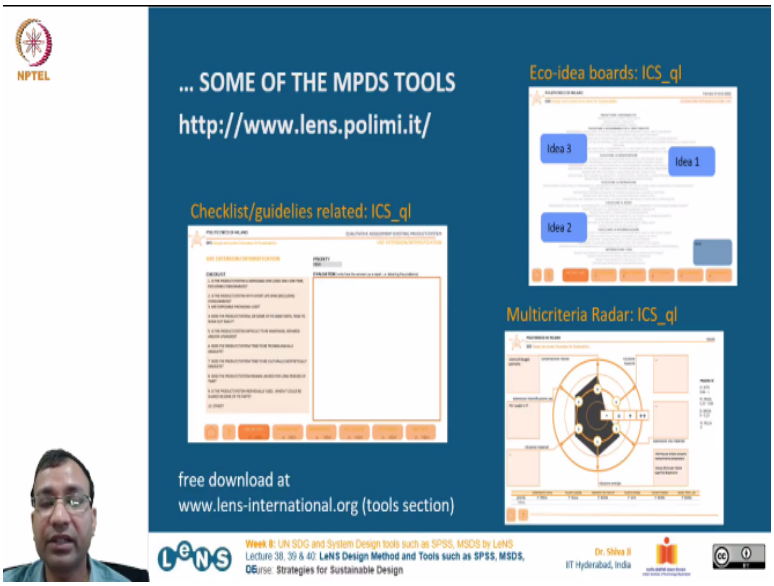
left column and process tools on environmental assembly and this assessment are given on this right column and how this exchange is taking a place in between.

So, you see it starts from the product strategies and the brief, so it goes on for LCA on reference product for design, so this is SIMAPRO is one of the LCA tools which gives knowledge about conducting the LCA and then from here you can go to this environmental design priorities identification from where you can identify the priority areas, where to intervene and how to intervene and then you can go to sustainability focused idea generation, you can go for conducting your brainstorming and this conceptualization, how to go for the intervention.

Further you can go for the product concept development etcetera and you can go for abridged LCA check, further qualitative studies and qualitative assessments also, then you can go for check for sustainability design priorities, you can use these tools IPSA and radar etcetera ICS which are given on this website of this LeNS Polimi.

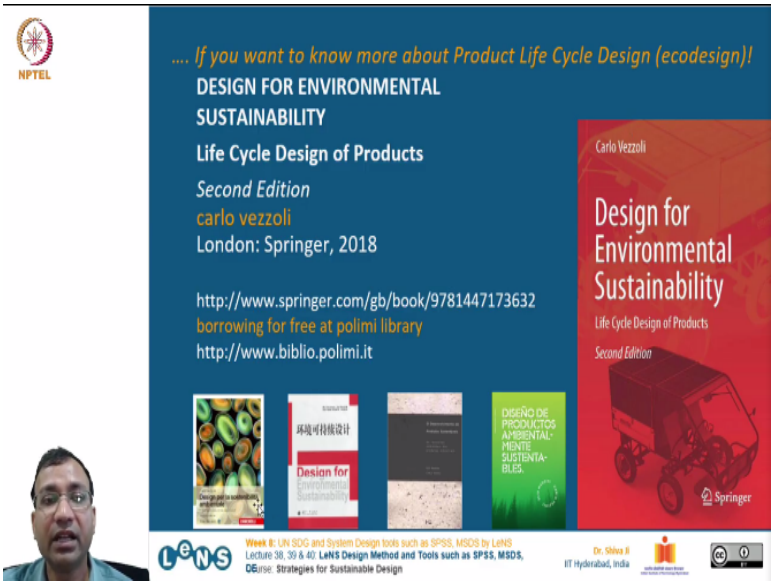
Further from here you can go for most promising concept selection, you can choose the best concept which seems relevant for the stage and from here you can go for product design and then again you can go for abridged LCA impact reduction etcetera using these tools and further again you can go for low environmental impact process selection, for manufacturing and a fabrication etcetera and also accordingly you can use, you can choose the tools and methods to undertake this exercise. And then further you can go for engineering the product, LCA of comparison for environmental quality communication that further lastly you can conduct another check for the final impact.

(Refer Slide Time: 93:19)



So, some of these tools and assessment methods are available free of cost to download and utilize in your design projects, you can visit this website, you can register as a member and you can avail these tools and you can utilize them in your design exercises.

(Refer Slide Time: 93:37)



Finally, these are reference some materials, more reading materials on this concept of SPSS, MSDS and DE you would be, I am sure you would be happy to go and refer these, you can be a member also on this platform, it is a interesting platform from where you get

to meet researchers and academicians and students from across the world, learning about their approaches how they are utilizing such wealth of this knowledge in their our own context, how well you can do so there is a lot of exchange also which happens periodically. So, with this have reached to the end of this lecture. Thank you everyone.