**Introduction to Sustainable Development and Sustainability Indicators**
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**Lecture - 26**
**Building Technology and Construction Management**

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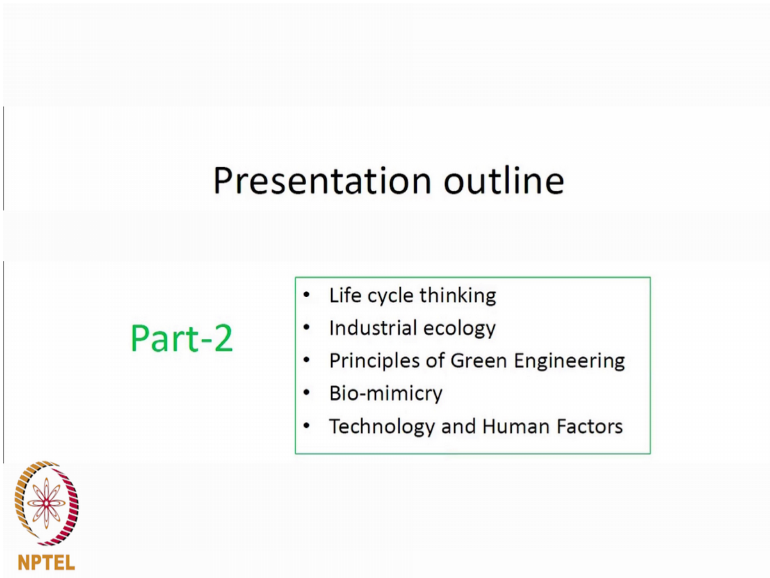


We discuss the difference between the primary energy use and the secondary energy use. Secondary energy use is the energy used by the end customers, whereas the primary energy use includes the resources associated with producing the energy as well as transporting the energy to the end customers.

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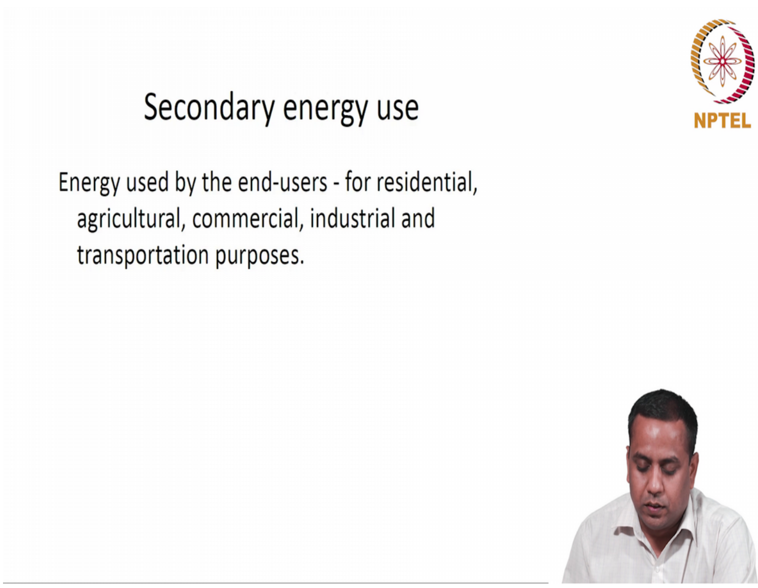


Now, the conversion of secondary energy to primary energy is influenced by a number of factors. For example, how the power is produced in the country, what portion of electricity is generated from each source. If we compare India and USA, more than three-fourth of the electricity is generated from thermal power sources. However, the emissions per unit amount of electricity generated in India is more than the emissions per unit amount of electricity generated in USA, because we use more coal for producing electricity, whereas us uses substantial amount of natural gas for power production.

Now, the power mix for each country varies from location to location. For example, in France 90 percent of the electricity is generated from nuclear power plants, whereas in Norway most of the power is generated from hydropower plants. So, the power mix for each country varies, and that influences the primary energy use associated with the energy consumption.

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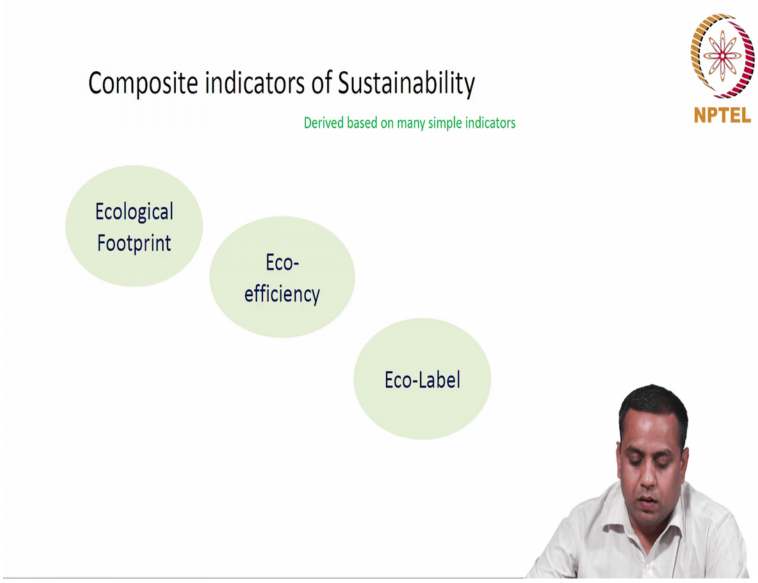


Now, we have covered the simple indicators of sustainability. The next section is the composite indicators of sustainability. So, we have three indicators, ecological footprint, eco-efficiency, and eco-label.

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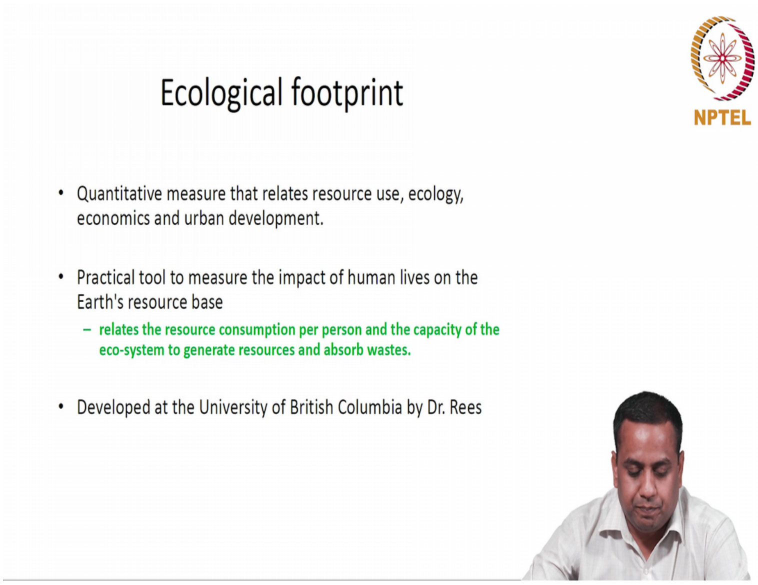


Ecological footprint is a concept developed at the University of British Columbia. Basically, this relates the resource consumption per person and the capacity of eco-system to generate resources and absorb wastes. This is a quantitative measure for assessing the resource use, ecology, economics and urban development.

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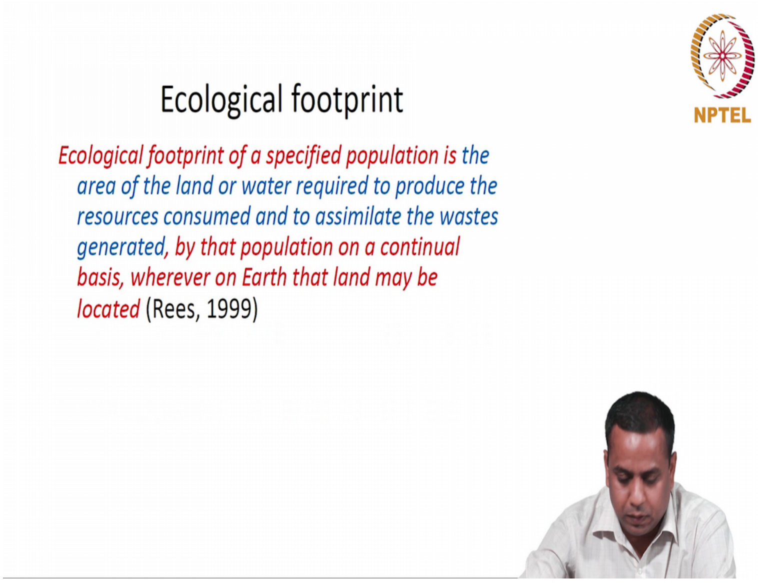


Ecological footprint is formally defined as the area of the land and water bodies required to produce the resources consumed and to assimilate the waste generated by that population on a continual basis, wherever on earth that land or water bodies may located.

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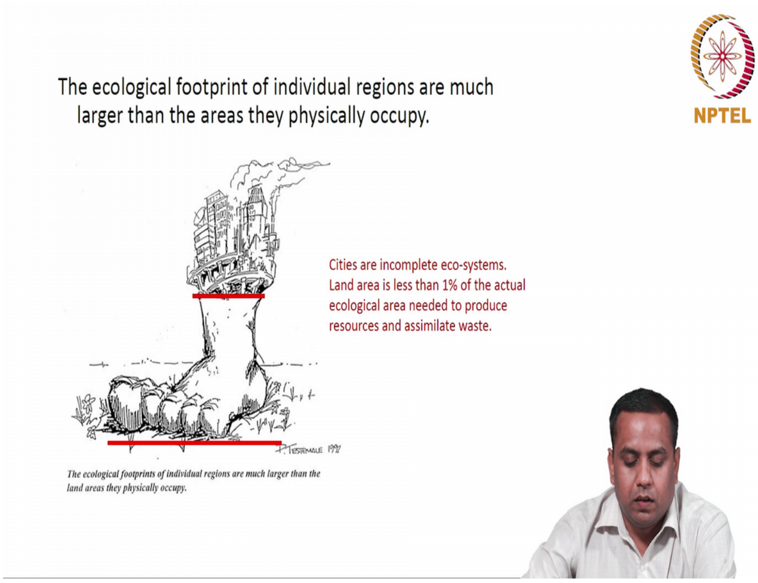


This picture symbolically represents, what ecological footprint as the the first line shows the area occupied by community or a city. And the 2nd line here, it shows the ecological footprint of that particular city. So, always the ecological footprint is much higher compared to the actual physical area occupied by the cities. So, this is one of the reasons why, we call cities as incomplete eco-systems, because the land area occupied by metro cities is less than 1 percent of the ecological, the aggregate ecological footprint of that city.

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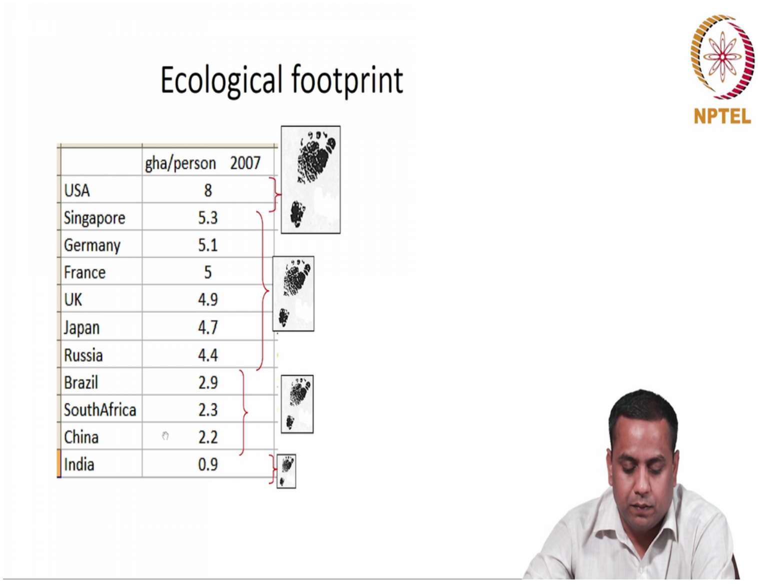


A comparison of ecological footprint of different countries. So, as we see from here, the ecological footprint of an individual in US is 8 times higher than an ecological footprint of a person in India. In Europe, it is about 5 times higher than India. China, South Africa and Brazil, it is 2 to 3 times higher compared to India. So, in terms of ecological footprint per person in terms of per capita carbon footprint, the lifestyle of an Indian citizen is much sustainable compared to any other country in the world.

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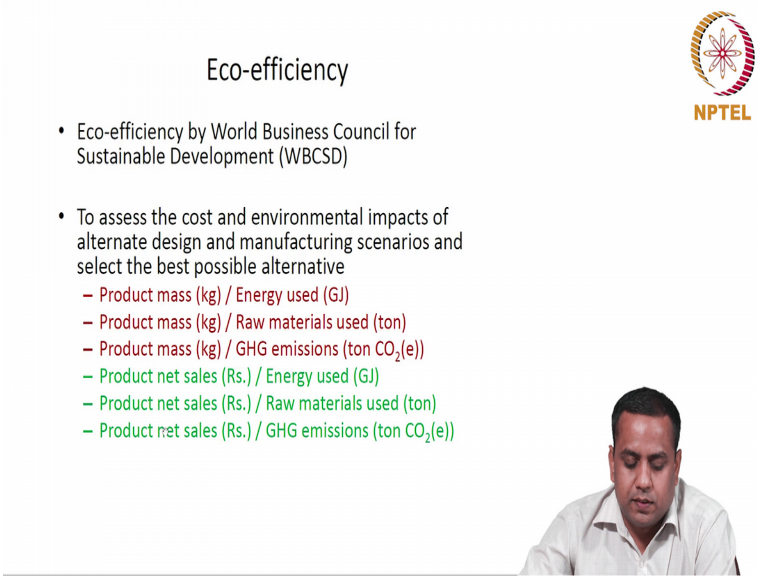


The second composite indicator for sustainability is eco-efficiency. Eco-efficiency is a concept developed by the World Business Council for Sustainable Development WBCSD. So, basically here we are trying to relate, the mass of the product manufactured, and the net sales of the product to the amount of energy used, the amount of raw materials used and the amount of emissions generated, during the product manufacturing. So, the basic idea is to evaluate the cost implications and the environmental implications of different design practices and manufacturing practices and choose, what is best in terms of cost and environment.

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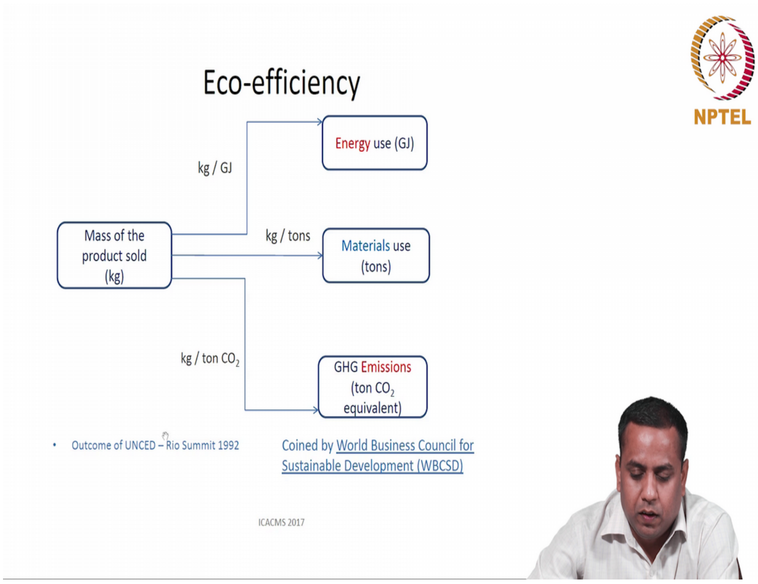

So, this figure graphically shows the concept of ecological footprint. So, we are relating the mass of the product sold to the amount of energy used, the amount of raw materials used, and the amount of greenhouse gas emissions generated from the process. The 2nd chart relates the net sales of the product to the amount of energy used, the amount of raw materials used, and the amount of emissions generated. So, basically the eco-efficiency relates the economic indicators and the environmental indicators.

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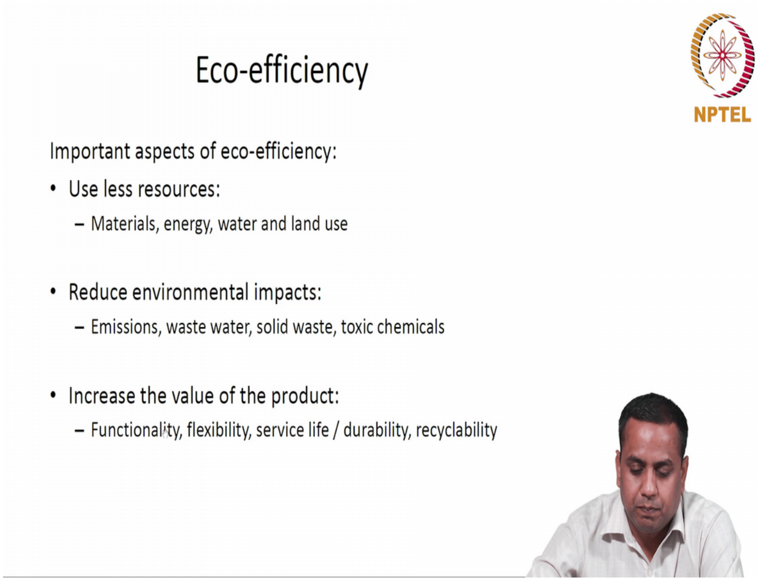


Now, what are the benefits of using eco-efficiency ratios for a product, so measuring eco-efficiency for a product helps us to use less amount of resources; in terms of materials, energy, water and land use. It helps to reduce the environmental impacts; in terms of emissions, waste, generator and toxic chemicals released into the environment. It helps us to increase the value of the product; in terms of functionality, flexibility, service life, durability, and recyclability.

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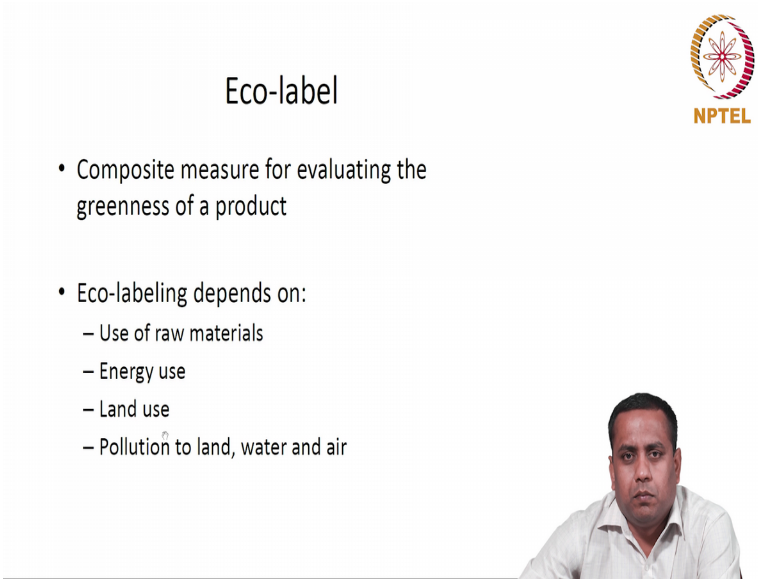


The other composite indicator for sustainability is eco-label. Eco-label is developed based on the use of raw materials, energy, land use, and pollution generator to land, water and air.

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See the first eco-label program in the world was released in Germany it is called German eco-label. This was created in 1977 to promote environmentally friendly products. So, the participation in this scheme is voluntary, it is a basic idea is to create awareness in preserving the use of natural resources.

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So, these are different examples for eco-labels. You know there are different ratings to state, how green the product as for example, the energy star rating by US the FSC rating for timber products. Eco-label rating by European Union and then, you know certification schemes for seafood and so on, so that completes the first part, where we have covered the definitions of sustainability, the life cycle of the product, and the different phases in the product life cycle, different definitions for sustainability. And, the indicators for sustainability the simple indicators, and the composite indicators for measuring sustainability.

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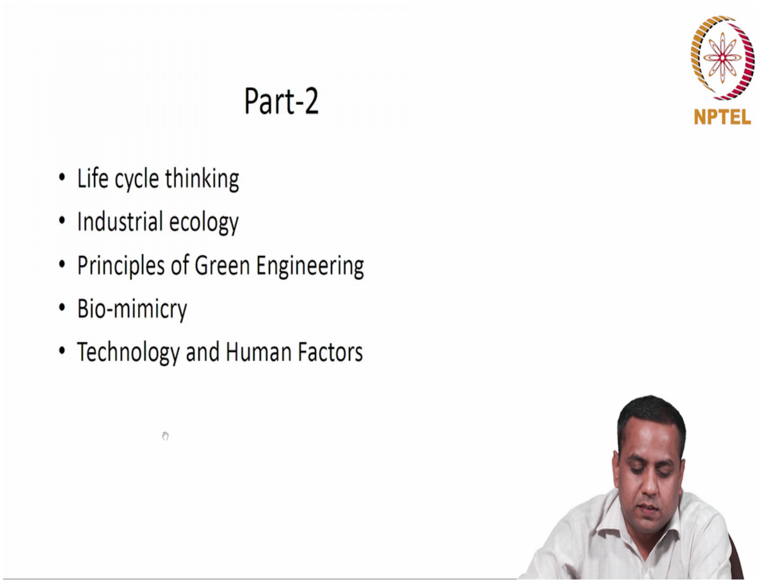

The second part we cover lifecycle thinking, industrial ecology, principles of green engineering, bio-mimicry and you know some information about the relation between technology and human factors.

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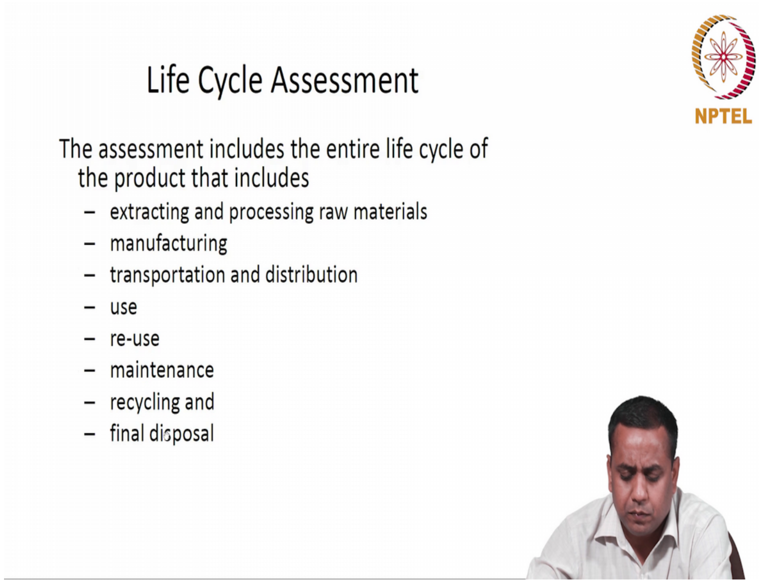


Life cycle thinking, life cycle assessment is a scientific technique used for evaluating the performance of a product in a holistic manner considering the entire life of the product, starting from mining of raw materials to the disposal of the product. So, we consider all phases of a product lifecycle, mining, manufacturing, transport, distribution, use, maintenance, repair, rehabilitation, disposal, recycling, and then land filling incineration and so on.

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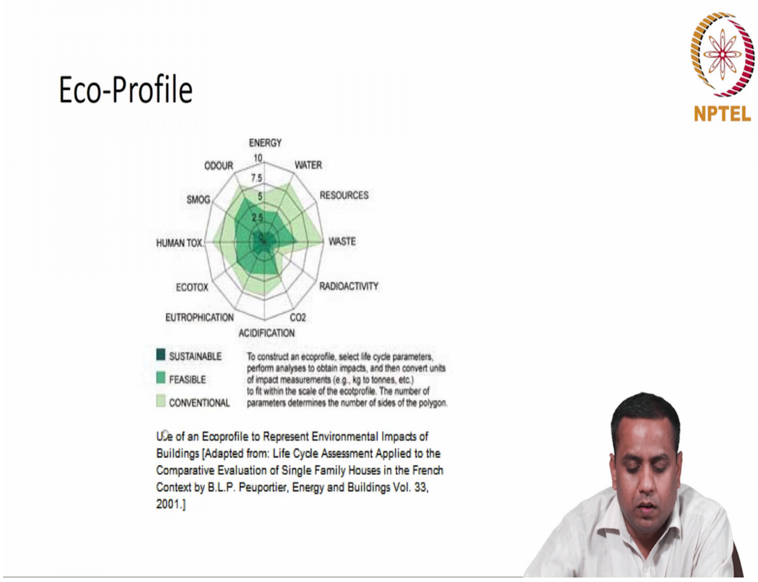


Now, the findings of life cycle assessment can be presented using a spider chat like this. This is called as an eco-profile, where we compare the performance of different alternatives on multiple indicators for example, energy, water, resources, waste, CO2, acidification, eutrophication, eco-toxicity, human toxicity, and so on. So, this is a very powerful plot to evaluate the sustainability performance of multiple alternatives for a product. So, in this case there are three alternatives considered. One is the base case, which is conventional, second is the feasible case, the third is sustainable case.

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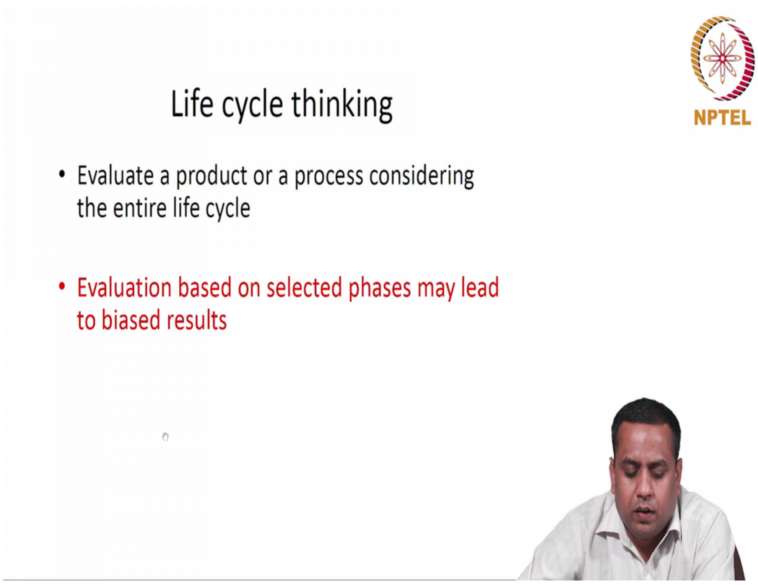


So, in case of life cycle thinking, we evaluate the product considering the entire life cycle. We do not come up with a biased opinion based on selected phases of a product.

For example, if I compare electric powered two-wheeler with the petrol power two-wheeler just based on the operational phase of the product, the conclusion will be the petrol power two-wheeler results in emissions. Whereas, electric powered two-wheeler produces zero emissions, but that is not the true picture, we have to consider the entire life cycle in evaluating the performance of the product.

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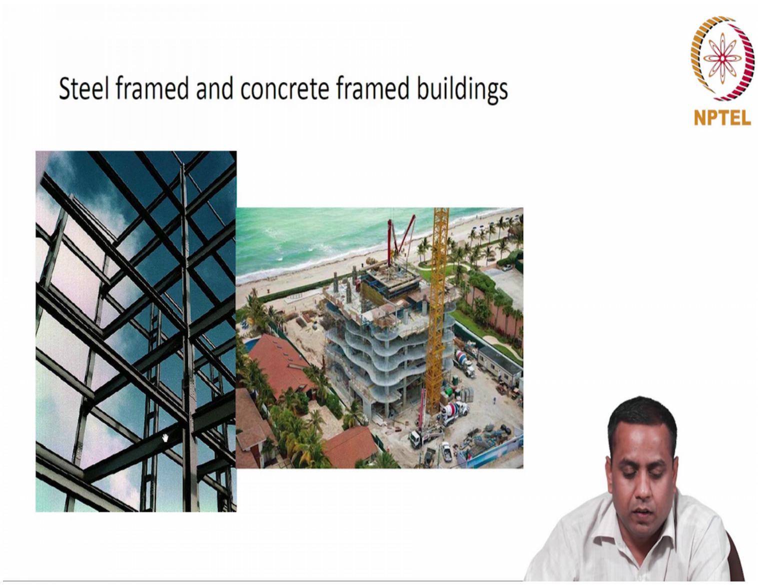


For example, I will illustrate the concept of life cycle thinking using this example. Let us consider two buildings the in the 1st building the core and shell of the building is made of structural steel. In the 2nd building the core and shell is made of reinforced cement concrete. Now, let us compare the lifecycle performance of these two options, and which is sustainable, which is producing more amount of impacts to the environment.

Now, let us compare by individual phases of the building life cycle. If I only compare the amount of materials used in these two buildings, the energy associated with materials in the first option that is the structural steel structural steel framed building is much higher compared to concrete building, because the embodied energy of steel higher than the embodied energy of concrete. So, as a result the total embodied energy, the initial embodied energy associated with the structural steel framed building is higher compared to concrete framed building.

Now, if we compare the site practices, the assembly of the building at the site, assembling a concrete building takes more energy compared to assembling a steel building in a construction site ok, because you know in case of steel building all we need is you know building and bolted connections. So, it takes relatively less energy compared to a concrete framed building, where we use several heavy machineries like a batching plant, tower crane, concrete pump, concrete truck and so on. So, based on materials steel building is more energy intensive, based on construction practices concrete framed building is more energy intensive.

Now, if we compare the operational phase of the two buildings, the energy use is expected to be comparable, because the core and shell does not influence, the operational energy much. So, the from the operational point of view, both buildings are expected to be comparable. Now, considering the end of life phase of the building, the demolition energy associated with steel framed building is expected to be less compared to the demolition energy associated with concrete framed building. So, in the individual phases considering materials, we conclude that a steel framed building is more energy intensive. Considering the construction and demolition practices, we can conclude that the concrete framed building is more energy intensive.

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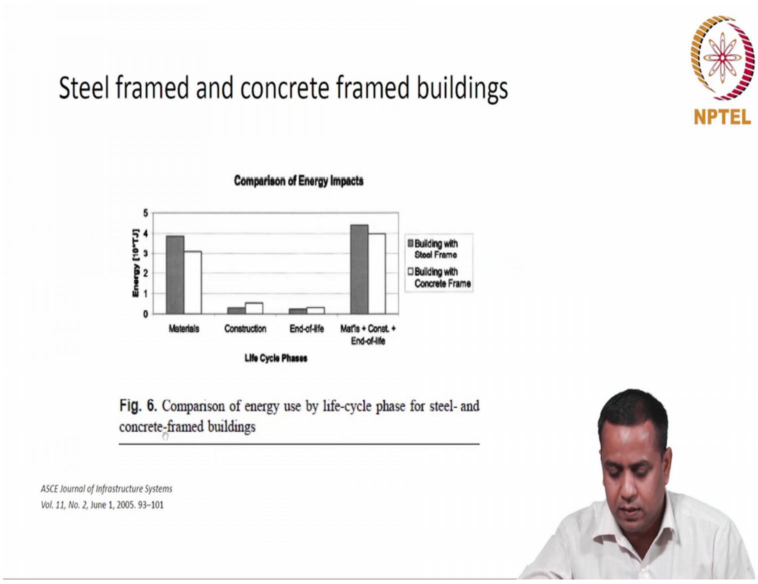


Now, if I compare the entire life cycle of both buildings, starting from materials to end of life, now the conclusion is that the performance of both buildings are comparable. One is not better than the other, both are comparable. And there is no significant difference in the performance of the two buildings that is what shown in this plot. So, this figure shows the comparison of a steel framed building and concrete framed building with respect to materials, construction, end-of-life, and then all phases together. So, this demonstrates the significance of using life-cycle thinking in evaluating the performance of any product. If we evaluate based on one or two phases, then there is high probability that we end up having a biased opinion about the performance of the product.

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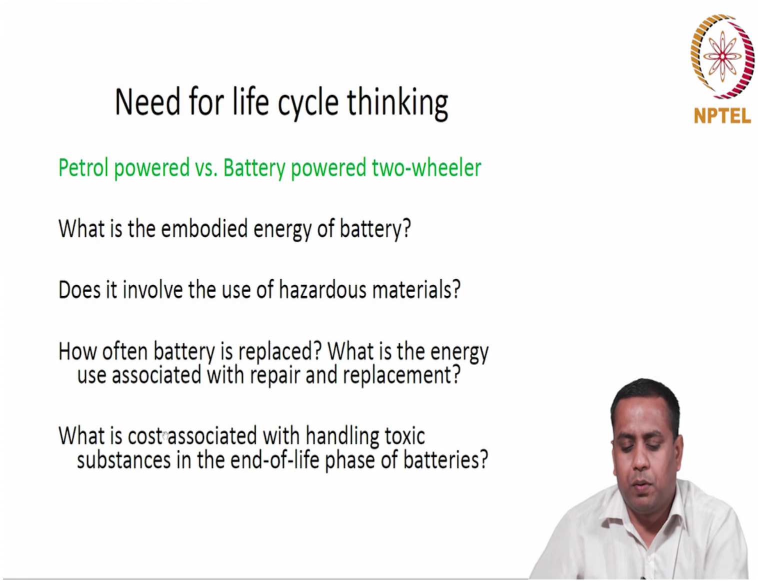


For example, I want to apply the concept of life cycle thinking for a two wheeler. Let us say, I compare a petrol power two-wheeler with a battery power two wheeler. Now, the questions that come to my mind related to life cycle thinking or what is the embodied energy associated with the battery used in the electric power two-wheeler or battery power two wheeler. Second is do we use hazardous substances in manufacturing batteries, third with respect to maintenance and repair work. How often the battery is replaced? What is the energy used associated with repair work and replacement? So, in other words, what is the recurring embodied energy associated with replacement of batteries during the life of the electric vehicle.

The fourth, what is a cost associated with handling the hazardous substances present in the batteries in the end-of-life phases of the component. So, to holistically evaluate the performance of a battery power two-wheeler with a petrol power two-wheeler. We have to answer these questions ok, then we will be able to say whether a petrol power two-wheeler is better or a battery power two-wheeler is better. Otherwise, you know comparing just based on the operational phase may lead to a biased opinion about the performance of the product.

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Now, we will also go through some principles of green engineering. So, this is related to the field of a industrial ecology. So, industrial ecology is basically the application of ecological principles to industrial systems or ecological restructuring of the industry. So, the basic idea of industrial ecology is rejecting the concept of waste. How to eliminate waste in terms of materials energy in the manufacturing processes. There, we improve the efficiency of the processes.

And how to close the life cycle of a product by connecting the end-of-life back to the product manufacturing, so that you know we are moving towards zero waste, zero emissions, to water and air. So, this is also a related to the Make in India movement, where we focus on zero defects and zero effects. Zero defects aimed to have no rework; zero effect focuses on zero discharge to air, land and water.

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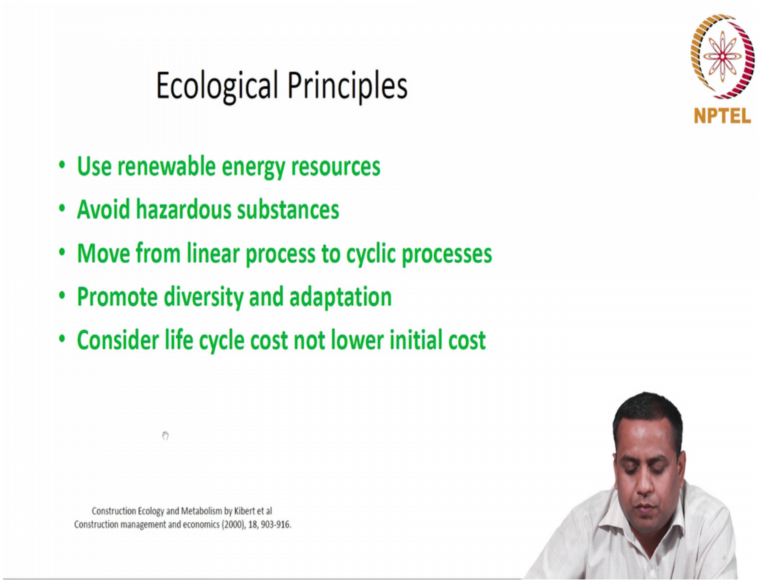


Now, what are the ecological principles that we are trying to integrate into the manufacturing processes, use of renewable resources, avoid the use of hazardous substances, moving from a linear economy to a circular economy, and then promoting diversity and adaptation in a manufacturing system, and then consider the entire life cycle cost not just the initial cost of the product.

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There are different ideas related to the field of industrial ecology, I have listed few here. The first is industrial symbiosis, which promotes the use of waste generated from one system as a useful resource input for another system. The second is design for environment, which focuses on changing the design process to promote a better reuse and recycling of the product in the end of life. The third is industrial metabolism, to understand the resources use and waste production to achieve resource efficiency. The fourth is cleaner production, which focuses on systematic reduction in material use and the control and prevention of pollution throughout the life cycle.

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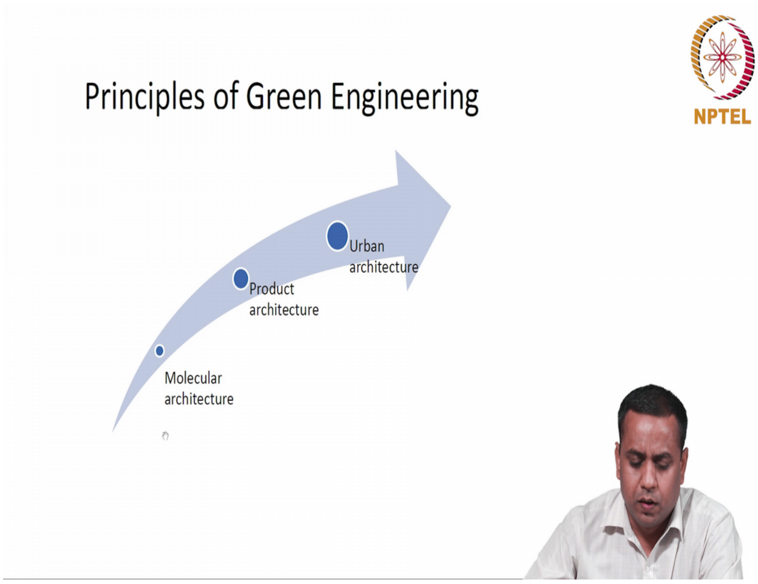


So, the 12 principles of green engineering that we are going to cover or generic in nature, it can be applied in any sector at any level. For example, it can be applied at a molecular level, it can be applied at the product level or it can be applied at the urban architecture level. Molecular level, for example designing a chemical, you know developing a chemical. Product level, developing a material or urban level developing cities, developing you know urban settlements and so on.

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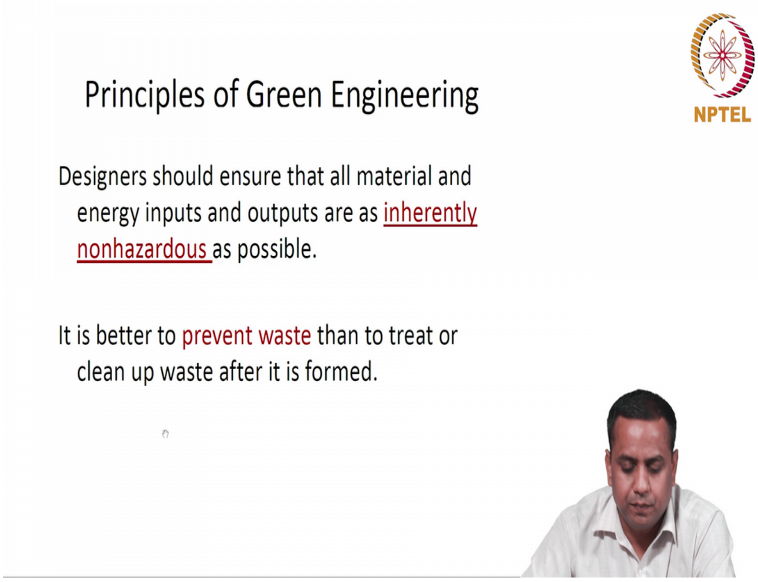


So, the first principle is designers should ensure that all materials and energy inputs and outputs are as inherently non-hazardous as possible. So, the basic idea is eliminate the use of hazardous substances in the supply chain, in the manufacturing, in the assembly processes. Thereby, we make the end-of-life treatment much simpler. Even, when there is a laps in the end-of-life treatment, there is no impact to the environment. The second is it is better to prevent waste than to treat or clean up the waste after it is formed. Prevention is always better than cure so, eliminate the generation of waste rather than treating them, after it is generated.

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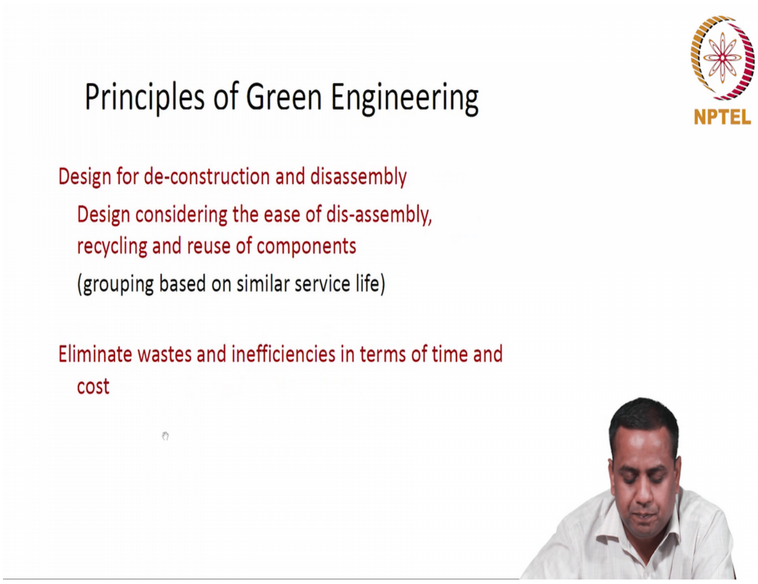

Third, design for deconstruction and dis-assembly. Consider the way the product will be disassembled and try to change the design practices in such a way that you maxim is recovery of useful components in the end-of-life. Fourth is eliminate waste and inefficiencies in terms of time and cost in manufacturing processes.

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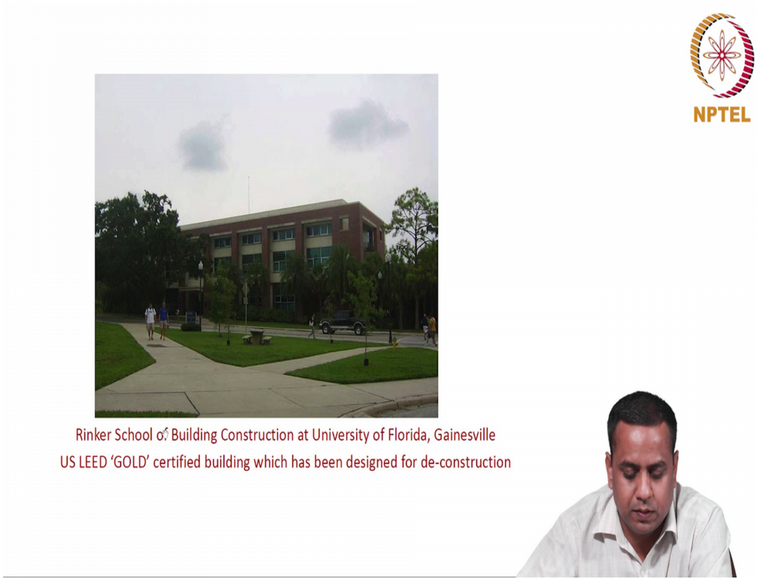


See for example, this is Rinker school of construction building in University of Florida, Gainesville. So, this is a US LEED GOLD certified building. This building has been specifically designed for de-construction, so that means, when the building is designed by the architect, they also have developed a demolition manual, which will be available to the contractor after the service life is over, so that demolition manual clearly states, how the building should be disassembled at the end of service life, there by maximizing the recovery of useful components you know, which can be used in other construction projects. So, this substantially reduces the amount of waste that is sent to landfills.

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So, the other principles of green engineering; it may be counterproductive to spend too much energy and cost to recycle complex product is it productive to recover the useful materials from a computer chip in the end-of-life, that involves the use of hazardous substances, then it is better not to recycle. The other principle whether to recycle a product or not-should be based upon material and energy investment. Avoid the use of hazardous substances or high amount of energy for recycling. If the recycling process involves high amount of energy or hazardous substances, then that can be avoided.

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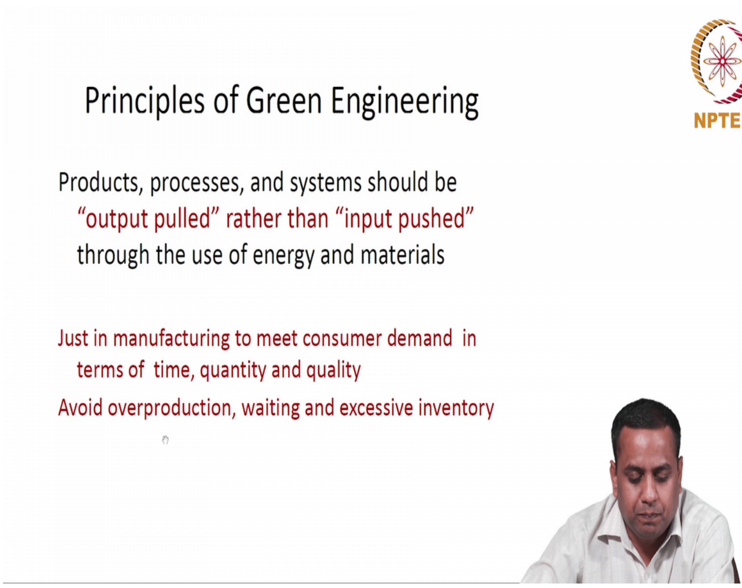


Products, and processes, and systems should be output pulled rather than input pushed throughout the use of energy and materials. Just in manufacturing to meet the consumer demands in terms of time and quantity and quality. Avoid over production, and waiting and excessive inventory buildup in the factory.

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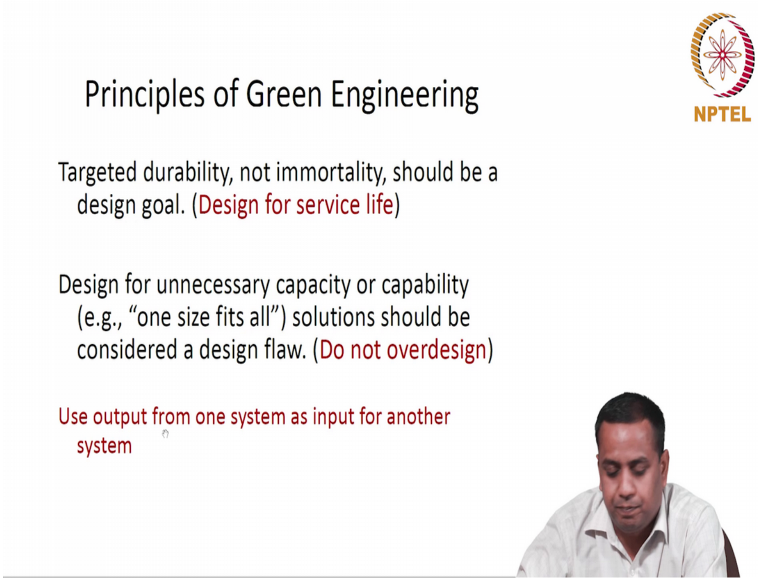


Targeted durability, not immortality, should be the design goal. In other words design the product exactly for the required service life, do not over design the product for eternal life ok. So, design for unnecessary capacity or capability, so that is one size fits all should be considered as a design flaw. So, basic idea is do not over design the product, design the product exactly for the required service life. And finally, use output from one system as input for another system, which is nothing but industrial symbiosis. For example, we use fly ash generated from thermal power plants as a useful resource materials in cement factories, where cement is manufactured.

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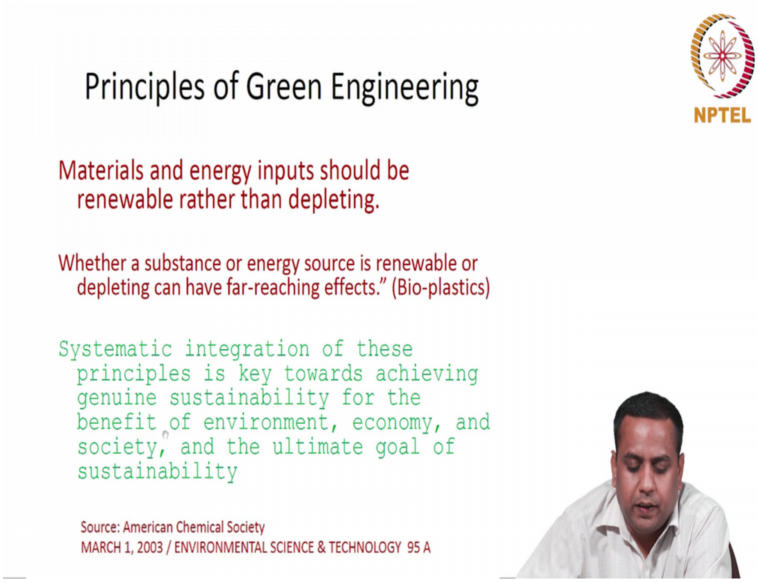


Materials and energy inputs should be renewable rather than depleting. Whether a substance or energy source is renewable or depleting can have far-reaching effects, for example, bio plastics and these 12 principles of green engineering will facilitate the moment towards sustainability. Systematic integration of these principles is key towards achieving genuine sustainability for the benefit of environment, economy, and society, and the ultimate goal of sustainability.

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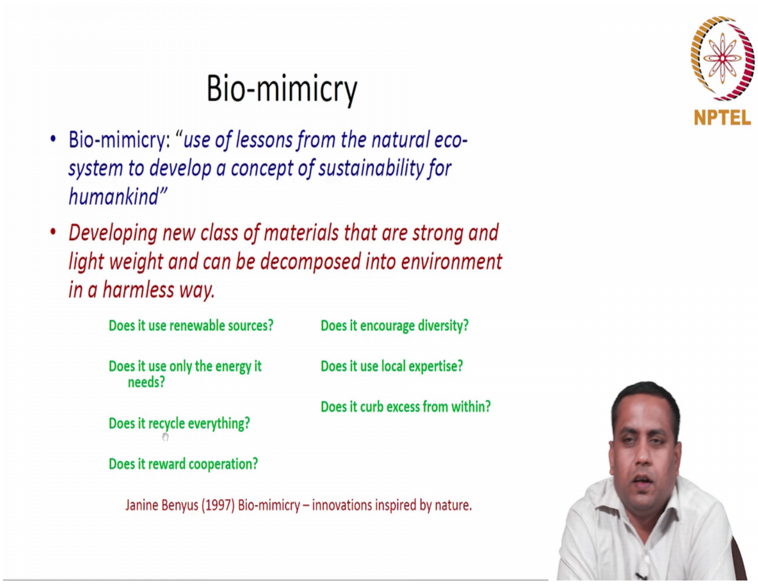

Bio-mimicry is basically the use of lessons from eco-systems to develop a concept of sustainability for humankind. So, developing a new class of materials that are strong, and lightweight and can be decomposed into the environment in a harmless way. So, basically in bio-mimicry we are trying to answer these questions, does it use renewable resources, does it use only the energy it needs, does it recycle everything, does it reward cooperation, does it encourage diversity, does it use local expertise. Does it curb the excess from within, these are some of the questions we are concerned bio-mimicry.

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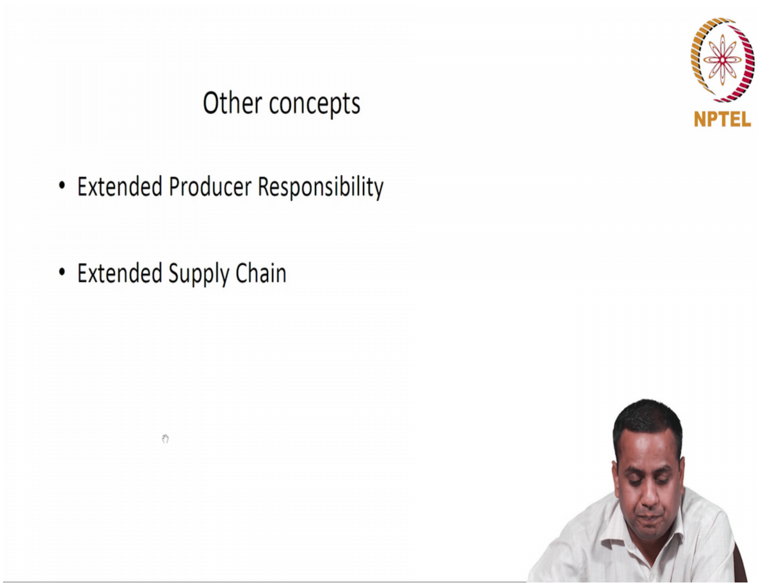


Other concepts related to sustainability extended producer responsibility, and extended supply chain extended producer responsibility, so basically the manufacturer of the product takes the responsibility to handle the end-of-life, after the service life is over. For example, this concept is predominant in Germany, where the manufacturer of a car, takes the product back after the life is over. The amount of waste that is sent to landfills is reduced, and the recovery of useful components from the product is maximized.

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Technology and human factors; so, if we consider the relation between technological improvement and human factors, human factors have more influence on the consumption of resources compared to technological advancement. For example, let us consider cars manufactured with better fuel mileage or the production processes that use less amount of energy and resources that is good, we are having better products, we are having better efficiency in terms of manufacturing the product.

Thereby we are using less amount of raw materials, but technology alone is not sufficient to make progress towards sustainability. Because, if you count the number of products sold in the market per year, the total impacts are much bigger compared to the technological efficiency achieved in the manufacturing. For example, what are the negative impacts of more product lined by the customers consumer oriented lifestyle. So, overconsumption, nullifies the benefits reaped to because of technological advancement in a country.

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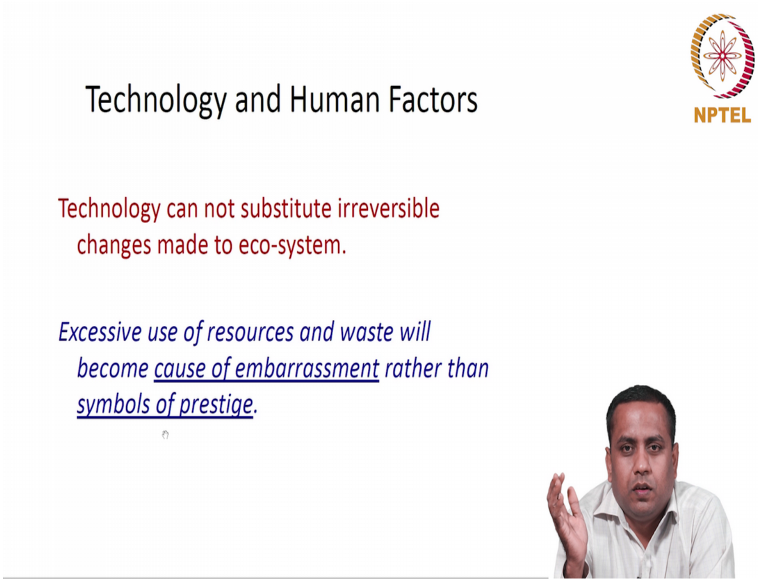


Technology cannot substitute irreversible changes made to the eco-system. Technology is not the solution for everything. So, unless the human changes his behavior, as unless the consumer changes his behavior, and make the lifestyle more oriented towards eco-system, technology only compliments that. Excessive use of resources and waste becomes a cause of embarrassment rather than rather than a symbol of prestige.

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So, finally what is the way forward, we have to leave eco-friendly lifestyle. Reduce, reuse, recycle remanufacture in any system. We have to de-energize, reduce the energy footprint of products, materials; de-carbonize, reduce the carbon footprints of materials. De-toxify, reduce the use of hazardous substances associated with manufacturing. We have to create more awareness among the consumers to have a lifestyle that matches the eco-system you know have an eco-friendly consumer behavior and lifestyle that is the final way to promote sustainability in the country. Thank you for your kind attention.

Thank you.