Sustainable Architecture
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Lecture – 13
Indicators and Terminologies in Sustainable Architecture

Good morning. Welcome back to the new lecture on Sustainable Architecture. I am Doctor Avlokita Agrawal, assistant professor at Department of Architecture and Planning, IIT, Roorkee.

In today's lecture we will be looking at the different terminologies and their definitions. The terminologies, which are used in some way or the other for defining and understanding sustainable architecture or green buildings. So, these terminologies are specific to buildings and built environment.

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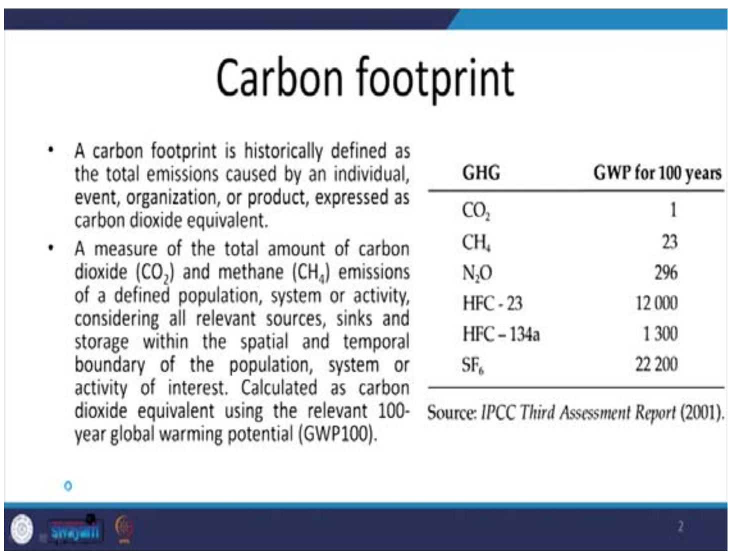

The first and foremost terminology which is very commonly used in our discussions around sustainable buildings is carbon footprint. Now carbon footprint is the total amount of carbon dioxide emissions which have the potential of global warming which is averaged over 100 years.

So, what we implied by that is that if there is any process or manufacturing of a product or construction process or any other activity the total amount of emissions which are taking place during that process will be converted to the equivalent carbon dioxide for their global warming potential.

For example, carbon dioxide is taken as a base which has a unit 1 global warming potential averaged over 100 years. However, if we look at methane CH_4, it has a GWP potential of 23, so 1 molecule, 1 unit of methane emitted is equivalent to 23 units of carbon dioxide emitted. So, 1 methane is equivalent to 23 CO_2 emitted.

If you look at nitrous oxide N_2O it has 296 CO_2 equivalents. For HFC and for HFC 23 and HFC 134a it has a much higher potential which is 12000 times the carbon dioxide and the sulfur fluorides they have even higher potential of 22000 times the carbon dioxide equivalent. Now, what we are trying to look at here is when we are constructing our buildings, we have to be aware of the different processes that go in it the different materials which are going in it and the associated carbon emissions.

For example, let us take any activity for that matter. For any sustainable building we advocate that the materials be procured locally. Now, say stone, which has a very low energy which is embodied in it. We will come to embodied energy, but very low embodied energy content.

So, for example, the locally available material. So, all sustainable buildings advocate the use of locally available materials for example, stone. Stone is a material which is very low on embodied energy. However, where is this stone being procured from? For example, I might have available stone which is locally available, while I might be wanting to use some exotic variety of stone which is to be fetched from a far of distance.

Now, to procure the same to procure the stone from a far of place the stone needs to be transported. The emissions which are taking place in all that transportation will be counted towards the carbon footprint of that material when we are talking about the building. The others for example, the HFCs and CFCs, now these are used in the air conditioning systems.

So, there are direct emissions and there are also indirect emissions. For example, the amount of electricity that we are using. Now, there is no direct emission which is taking place it might seem to be a very clean energy source. However, at the point where the electricity is being produced for example, if it is being produced using thermal power plant where coal is being burnt, coal is being used as a fuel or gas or other forms of hydrocarbons are being used as a fuel there the amount of carbon dioxide equivalent which is emitted is the is counting towards the carbon footprint.

For example, if we are using cement. Now, cement has very high carbon footprint simply because not just cement, but any other material which is produced at very high temperatures, so that causes the nitrogen oxides to form in the atmosphere. And there, we have already seen that it is 300 approximately; 300 times the global warming potential as carbon dioxide. So, we have to understand what each material amounts to how much global warming potential does each material have in comparison to carbon dioxide and higher this number higher is the carbon footprint.

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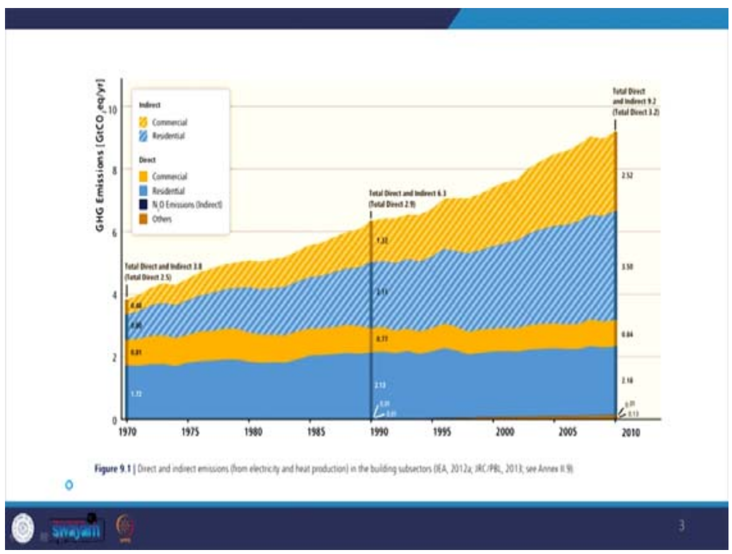

If we look at this data from IEA, it is very clearly seen that as we are progressing the direct emissions from buildings are remaining almost constant, but it is the indirect emissions which is what we just talked about. For example, the electricity which is generated elsewhere not at the building side. So, those indirect emissions are increasing every day as the lifestyle is changing as the type of buildings are changing as we more and more buildings are becoming air condition. So, these indirect emissions are increasing.

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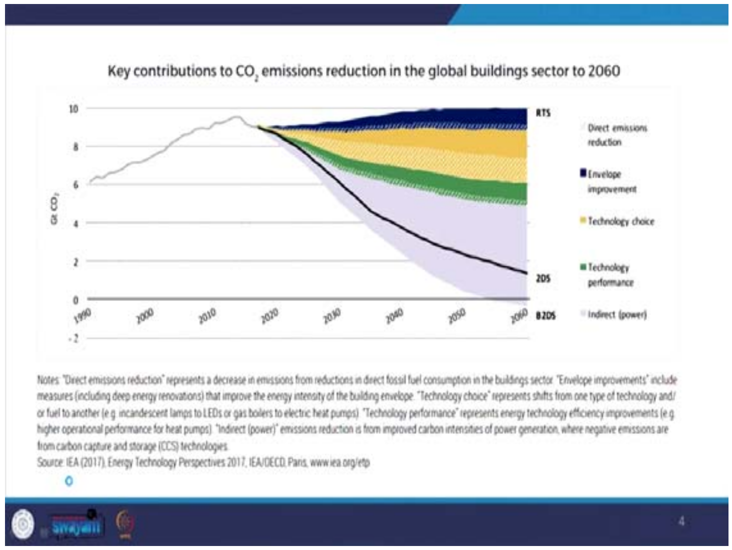

The same is seen here, but depending upon our strategy what kind of strategy do we adopt, what kind of way forward do we adopt, we can limit these carbon dioxide emissions, carbon footprint to bring it down or to retain at the same level depending upon what are the different alternative courses we take.

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If we look at this footprint calculator.

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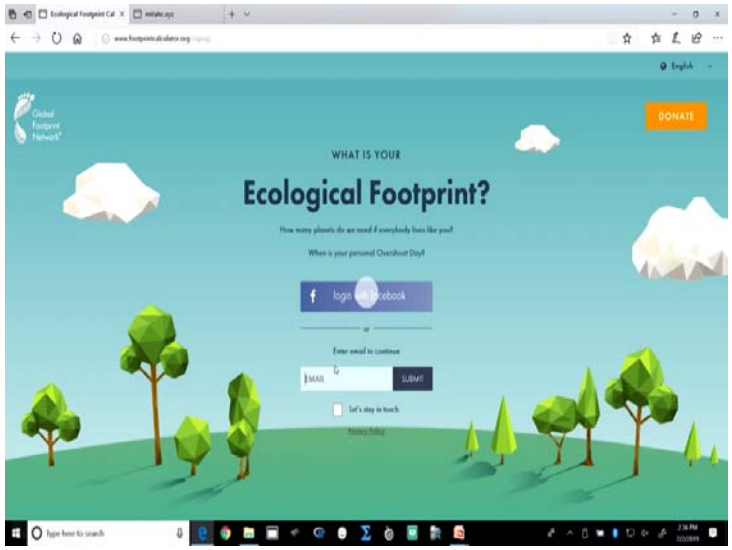

So, some very interesting footprint calculators are available online and we can get to know our own footprint, but this is ecological footprint. This is not carbon footprint, but it takes into account the carbon emissions largely.

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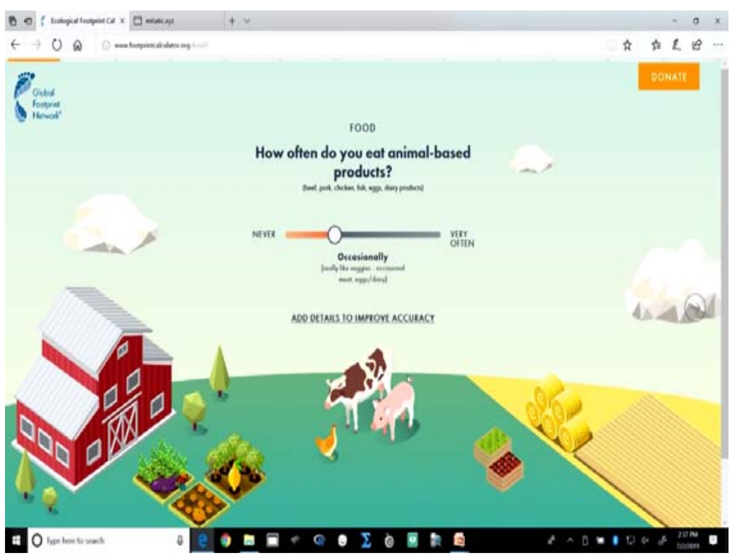

If you follow this website and you calculate. So, it gives us what is our footprint based upon the lifestyle let we choose, whether we eat meat products or only vegetarian diet.

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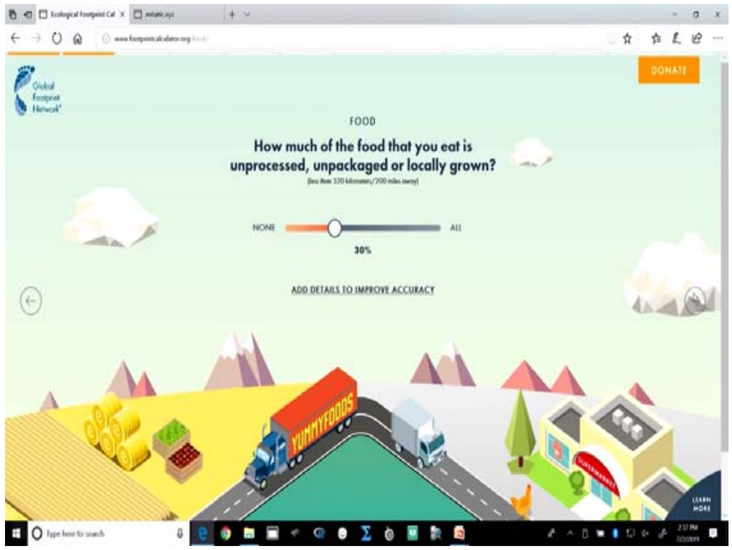

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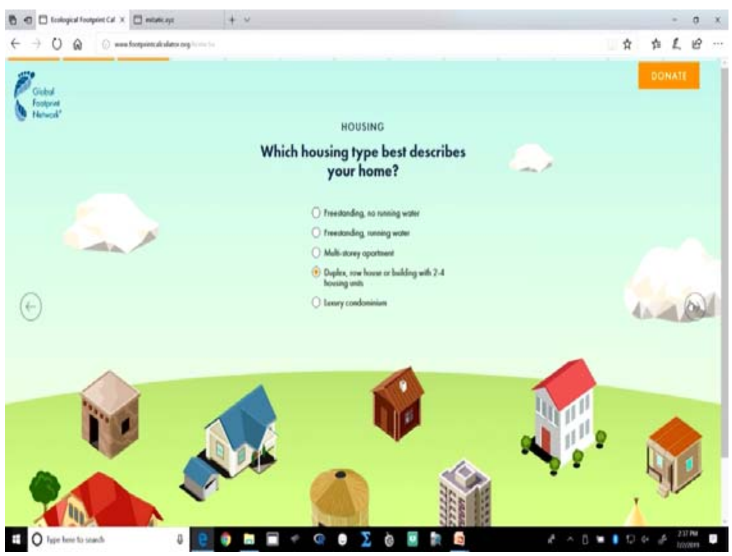

From where is the food procured to the kind of housing we live in, to the kind of house we live in.

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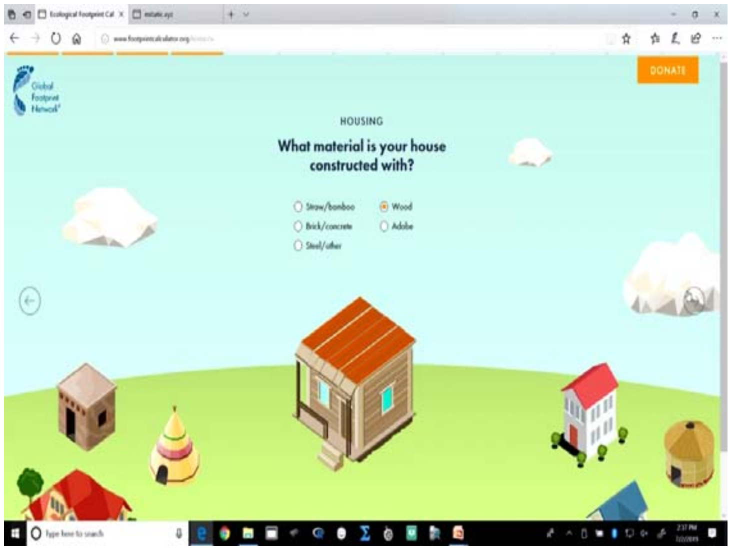

And are the materials which we are using.

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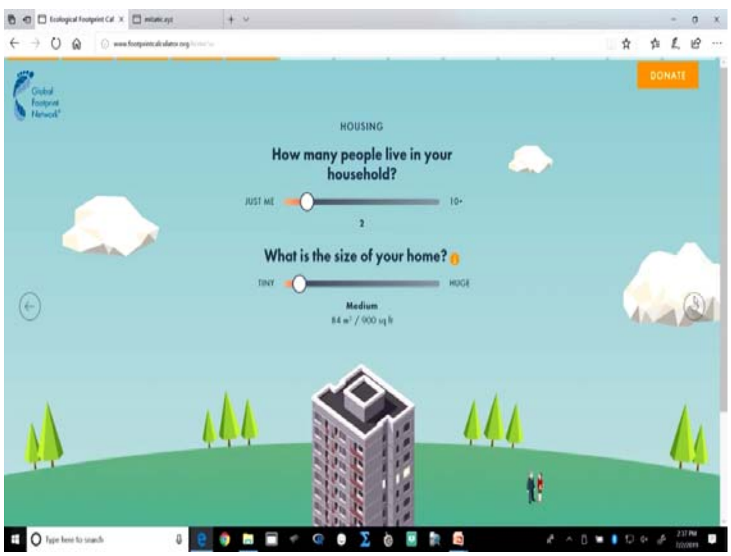

The per capita space that is being consumed and also the electricity consumption inside the home.

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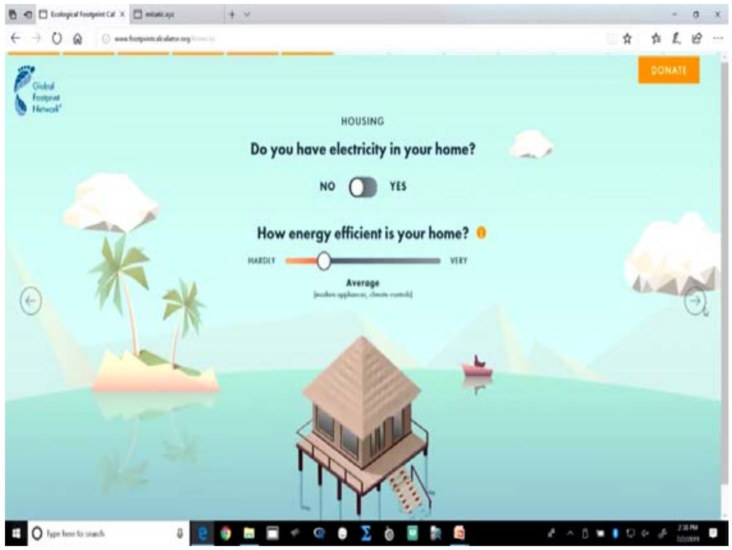

The kind of appliances we are using.

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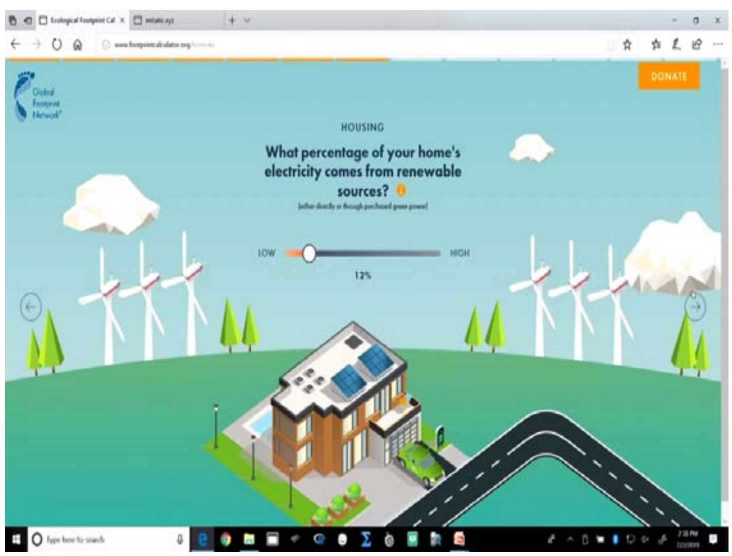

The type of electricity which is being used inside the home whether it is renewable or from non-renewable sources.

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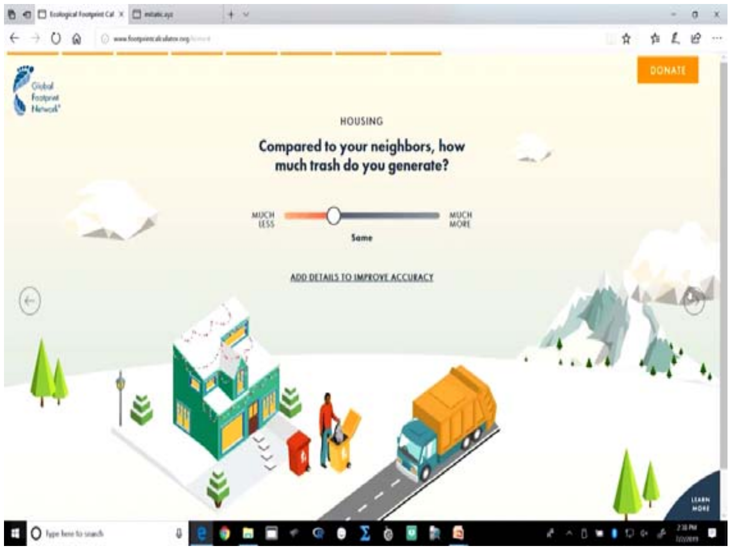

The type of waste we generate and the amount of waste we recycle.

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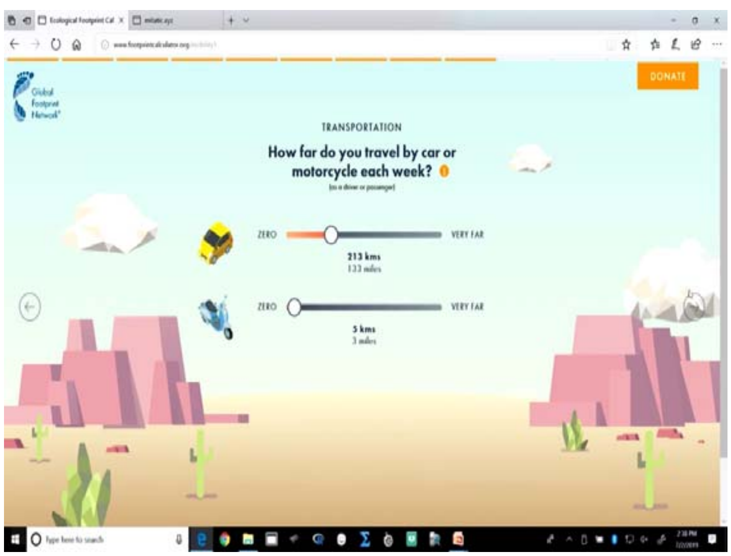

The kind of transportation mode we use cars, scooter, bicycle.

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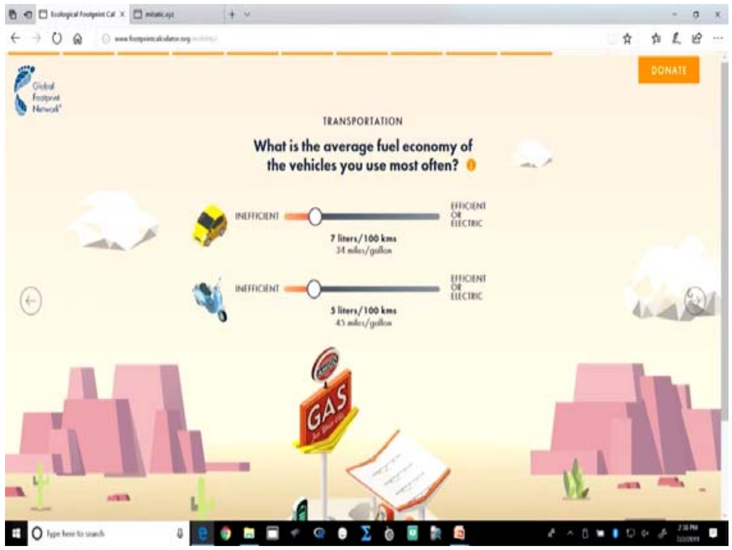

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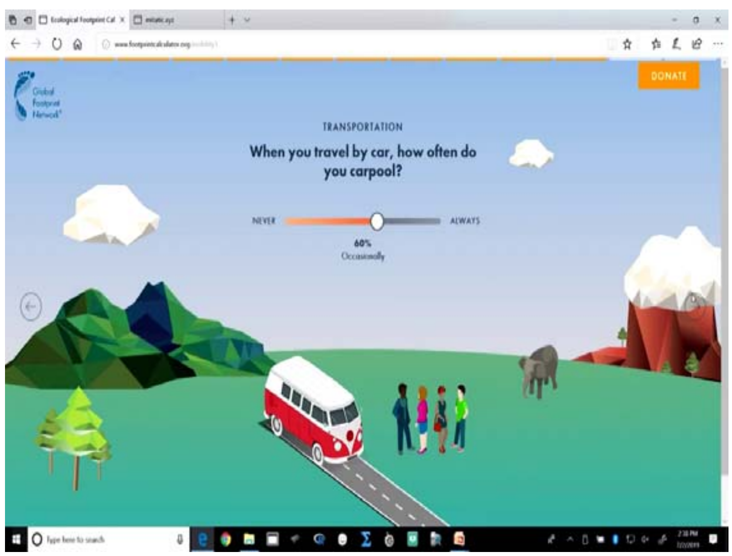

And the efficiency of car that we drive.

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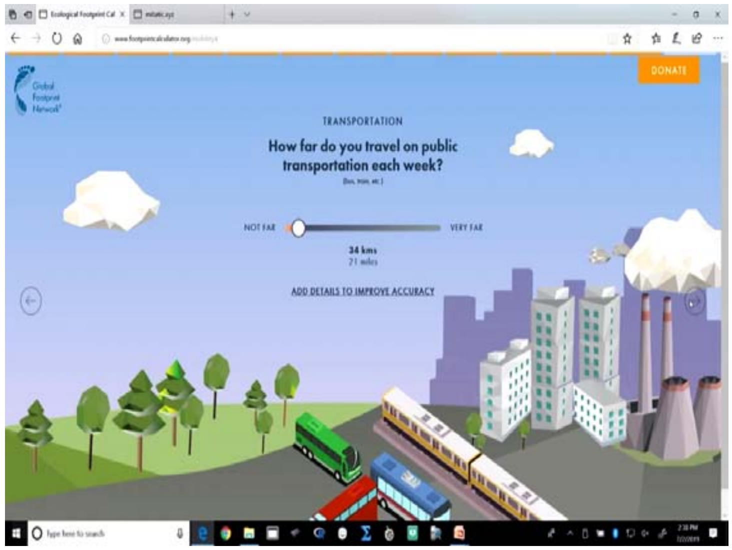

Whether we carpool or not, or whether we use public transportation and the major component is whether we fly, whether we use air transport in each year.

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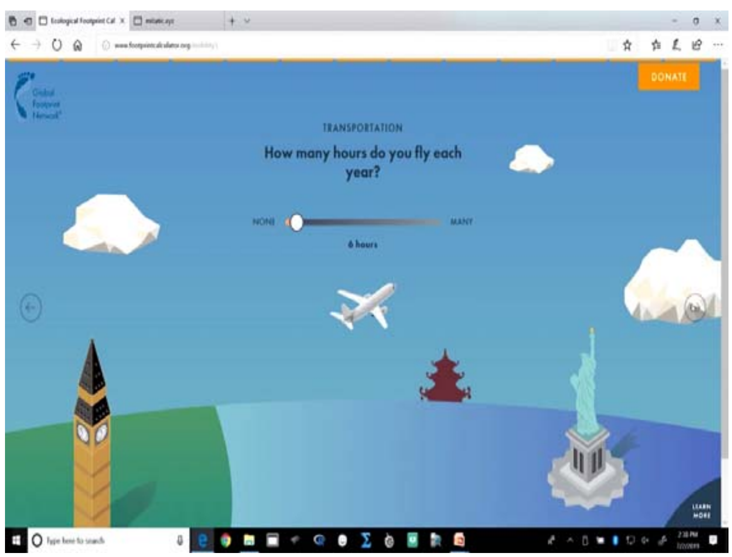

And together it gives how much of the resource is consumed if we go on living the same way as we are doing.

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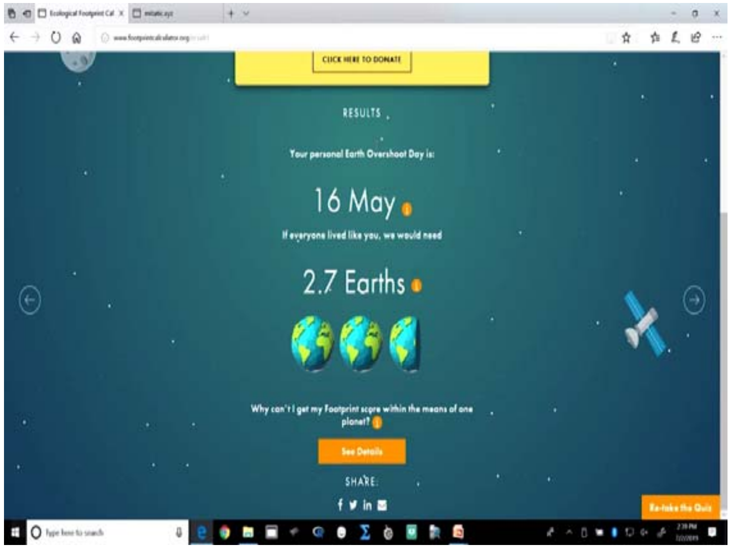

So, I have not changed much, but we can see that the overshoot day which is another concept which we have discussed previously that we require around 2.7 earths if everyone on the earth lives like the way we do. And we can reduce our carbon footprint if we consciously try to do that.

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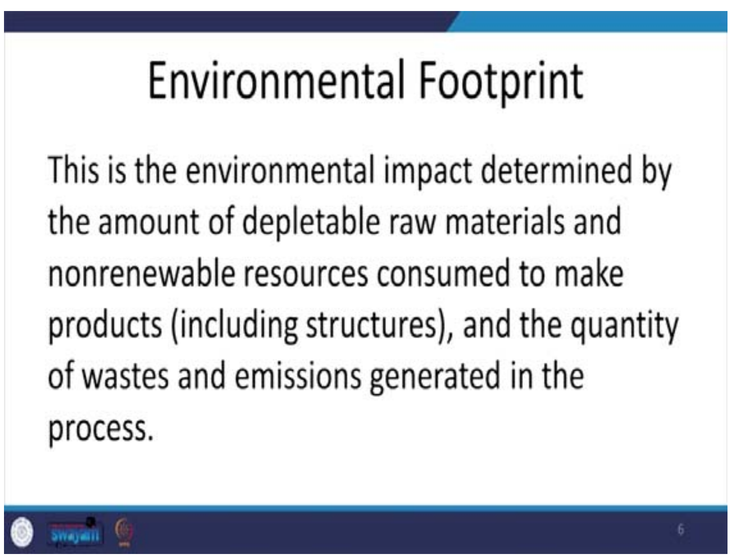

The next terminology is environmental footprint. Now, environmental footprint talks about the impact determined by the amount of depletable raw materials and non-renewable resources consumed to make the products. Here since we are talking about buildings, we will be talking about the resources which are consumed to make these buildings. And the quantity of waste and emissions generated in the process.

Here we are looking at the environmental resources which will be required. Say for example, for constructing a building we require wood, so we require land from the environment, we require forest, we require energy for making the building, we require stone, we may require water. So, each of this component of the environment is counted it is a resource from which is being borrowed from the environment and that is all what counts towards the environmental footprint.

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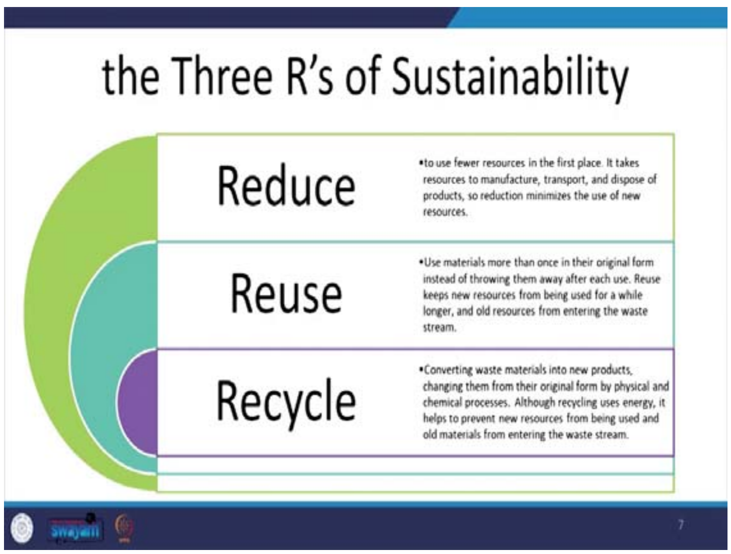

The next terminology that we commonly use for defining sustainability and we call them the 3 hours of sustainability, reduce, reuse and recycle. By reduced it implies that the amount of resource which needs to be consumed has to be reduced it is demand reduction. So, the amount of energy that we require for cooling has to be reduced, the amount of water that is going to be consumed has to be reduced, the amount of materials which are going to be used they have to be reduced.

So, the first strategy for achieving sustainability not just in buildings, but in any other domain is to reduce the resource consumption. Once we have reduced the resource consumption, the second strategy which comes is reuse. Whatever is being used has to be reused again. For example, the wood which is in good quality can be reused for some other purpose. Brick can be reused; the construction and demolition waste can be reused.

So, the water can be reused and like that. So, the second strategy would be to reuse. ~~First~~First, we have reduced the amount of resource required, second is once we have used the resource it can be reused in some other form.

Even after reusing when the waste is generated the third strategy comes into place which is the recycled. So, the waste out of the first two processes is then recycled to transform it into some other usable form which is the recycling.

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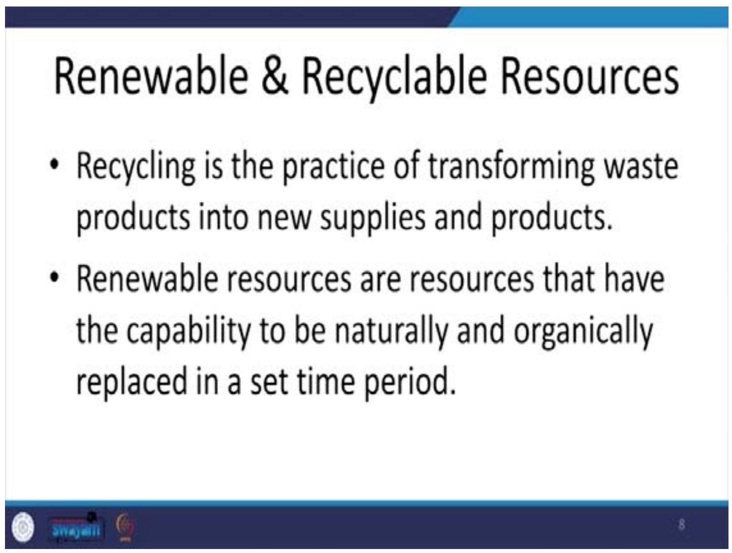

Another terminology which is also related to these is renewability; recyclable, resources we have seen, but renewable resource. Now, renewable resource is a resource that has the capability to be naturally and organically replaced in a set period of time. For example, using bamboo as a construction material. Now, bamboo as a material it grows very fast and ~~we can~~ it can is a renewable resource we can use it.

For example, the solar energy, the electricity which is generated using the suns energy, so that is a renewable form of energy. It is abundantly and naturally available to us. Electricity which is generated using hydro, the hydropower is a renewable form of energy. So, renewable resources are the ones which are naturally replaced or renewed in a such time period.

The recyclable resources as we have already talked are the ones where we can transform the product by some process to make it into a reusable product.

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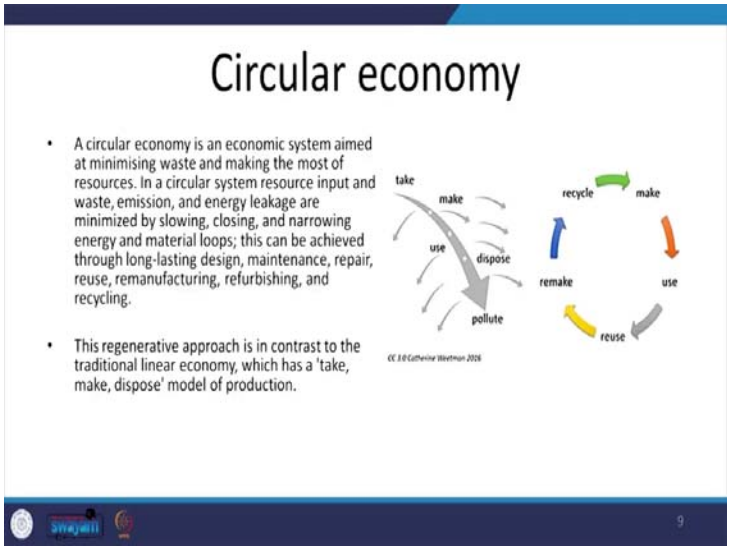

Another new concept which we have is off the circular economy. Now, circular economy is very synonymous to sustainability and the system thinking where nothing goes as waste. So, earlier the approach was to take, make, use, dispose and pollute. So, we take it, take it from the environment, take the resources from the environment, make it, transform it, use it and then we dispose it off and which eventually goes back to the environment to pollute the environment.

However, in a circular economy, we have the economic activities and this entire thing goes in a cyclic manner in a closed loop, where we make use and we reuse it. After reusing it we remake it by recycling and make it again, that is how the entire cycle goes in. The economy is associated with it at each step. There are economic opportunities which are generated along with the system within the closed loop.

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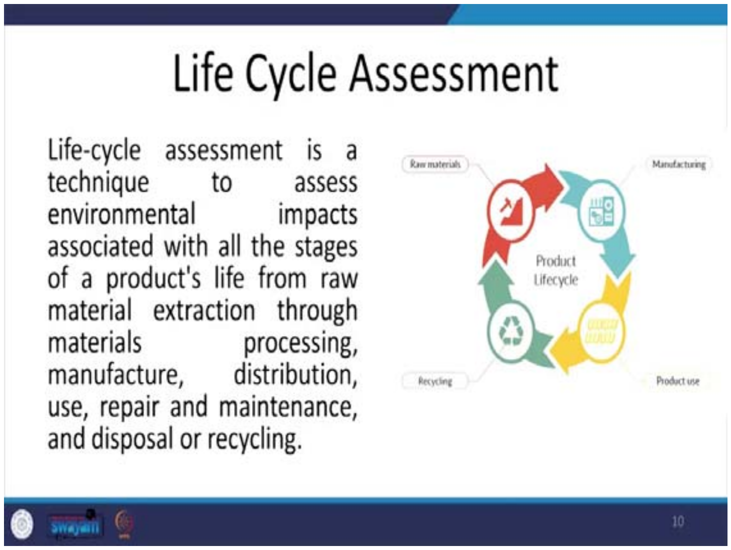

The next very important terminology which we often come across is lifecycle assessment. Now, life cycle assessment is a technique to assess environmental impact associated with all these stages of a products life that is from the raw material extraction to its processing, manufacturing, distribution, use, repair maintenance and final disposal or recycling. Ideally recycling, but in some cases the disposal. So, the environment impact which is associated throughout the products life cycle is taken into account when we are talking off life cycle assessment.

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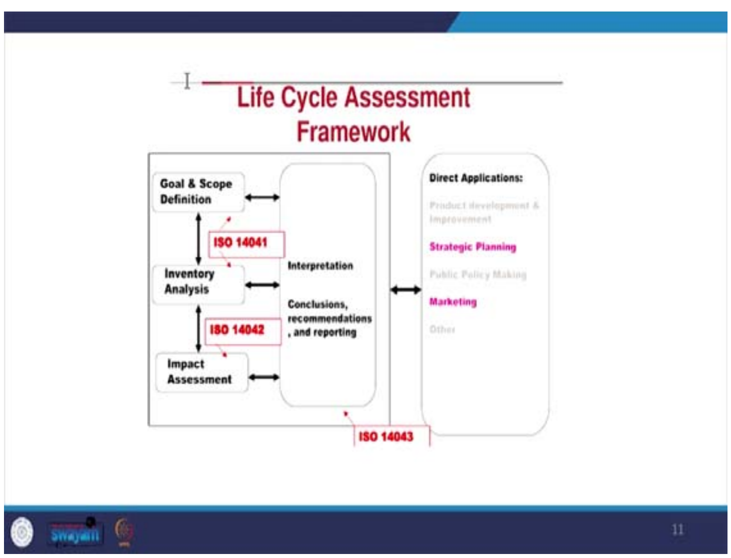

There are some specific IS ~~is~~ codes ISO 14041, 42 and 43 which defines how lifecycle assessment should be carried out. Very simply, lifecycle assessment requires a goal to be defined and the scope of the work to be defined. When we talk about life cycle assessment since we have been talking about it since beginning that the entire discussion around sustainability emerges from this system thinking. So, nothing is isolated, nothing is standing in isolation independently, everything is interconnected.

So, when we are talking about life cycle assessment probably there would be no process system in the world which is not connected to the other some way or the other. So, we have to define how much is within the scope of this work. What is the goal? Are we looking at energy? Are we looking at water? Or are we looking at environment largely? Or are we focusing on some other issue?

So, depending upon that we define the goal and scope and then we look at the inventory whatever is existing or whatever is coming in and going out. For example, say a building and we define that, ok. We want to look at the life cycle assessment of a building starting from its design stage do its post occupancy and demolishing. Now, that is a huge scope of work.

Now, the inventory would be all the raw materials which are coming in, all the operational resources which are coming in and what is going out as waste as the impact on the environments, all of that will be covered. This is inventory analysis and then we talk about the impacts what are the impacts, environmental, ecological impacts. All of that together is consolidated into one single report and it is reported. This helps in developing the strategy plans and the policies related to improvement in the performance of a product or process or any other activity.

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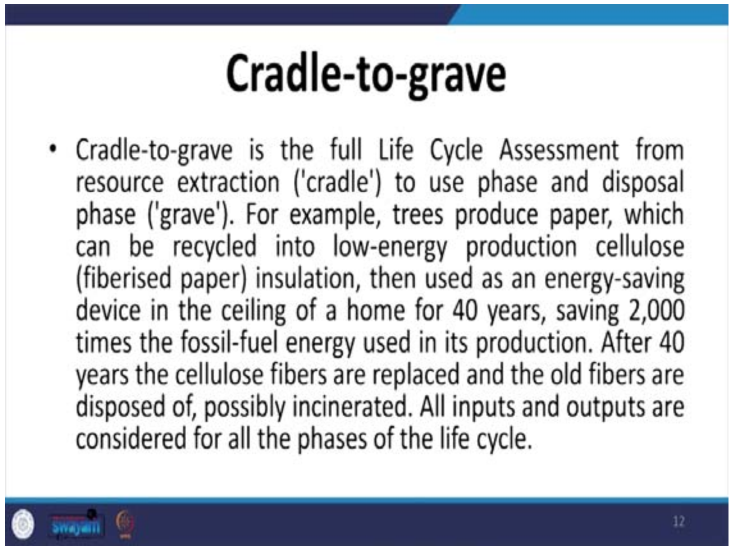

Associated with lifecycle assessment there are couple of other terminology which are synonymously used, but they slightly vary. So, one is cradle-to-grave. Now, cradle-to-grave implies the raw material resource extraction from the environment from the nature that is the cradle and grave implies to the last stage where we are talking about the disposal, if it is not circular or the recycling where the current form of the product is ending and it is being recycled into transformed into some other product. So, that is cradle-to-grave.

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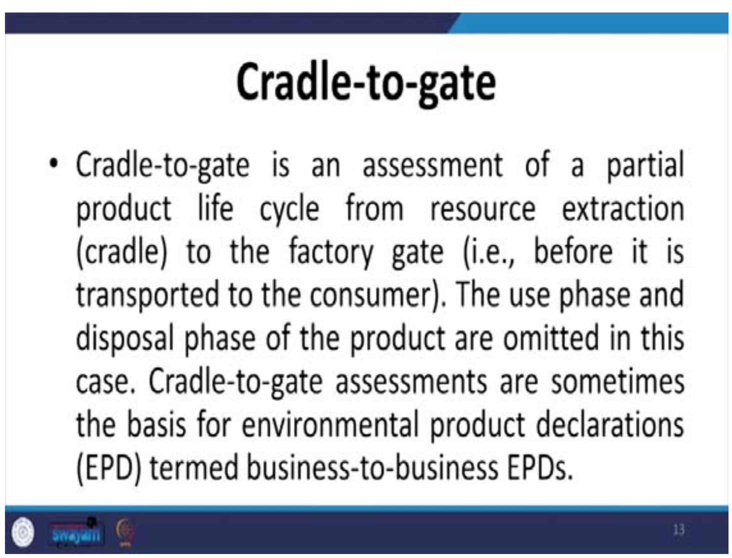

Cradle-to-grave is the most comprehensive assessment techniques assessment types where the entire life all the phases of a products life are covered. We have others for example, cradle-to-gate. Now, in cradle-to-gate, we are starting from the resource extraction the raw material resource extraction, but considering it only up to the gate of the factory after the processing and manufacturing is complete before it is transported to the consumer.

So, we are not taking into account how it is being transported, how it is being used, implemented in the building or wherever. So, we are only concerned with the raw material extraction, its manufacturing, processing and its ready to use kind of from up till factory gate that is cradle-to-gate. We also have cradle-to-cradle where from cradle-to-grave one more step is added where it is circular economy and the loop is closed.

So, from one product, the waste of one product we are sending it to the raw material of the next product that is cradle-to-cradle approach. The gate-to-gate approach will be where the, we are not talking about the manufacture the raw material extraction, we are only looking at the product from one gate to manufacturing and processing of product to another gate, where we are not looking at the complete cradle-to-gate or cradle to cradle evaluation, we are only looking at the specific parts of the production process.

The next one we are looking at is ecologically based LCA. There is a slight difference between the LCA Life Cycle Assessment and ecologically based LCA. In Life Cycle Assessment LCA, which we just talked about we are largely looking at the environmental impacts, but from a defined scope and perspective.

While when we are talking about the ecologically based LCA, we are looking at the at a much broader range of ecological impacts, possibly all the ecological impacts are considered. Here we are not limiting the ecological impacts to a defined scope, though the scope of the work is defined, but all the ecological impacts, which are governed which are present within the given scope are~~ concerned~~ considered.

Another related terminology which is related to life cycle assessment is life cycle energy analysis. In life cycle energy ~~analysis~~analysis, we are looking at the entire life cycle of the product or process, but we are looking only at the energy aspect of it. So, how much of the energy is consumed from its raw material extraction to its, say disposal or recycling the through the entire life cycle we are looking only at the energy consumption.

So, we are not looking at the environmental impacts, the ecological impacts or any other costs associated with it, except energy.

We are also looking at a synonymous terminology which is Life Cycle Cost Analysis LCCA. Now, here it is very similar to life cycle energy analysis, but here we are looking at the cost economic costs of each of the component each of the process. So, we are converting all the processes and resources which are being consumed during the life cycle of a product or an activity in terms of its economic value, in terms of its cost and together that is a very good measure of comparing product to product.

And it is a very effective tool, both life cycle energy analysis and life cycle cost analysis are very effective tool and specially lifecycle cost analysis because we are converting everything into the cost numbers which is tangible. ~~Also~~Also, anything which is resource exhaustive, it might be any resource for that matter will always have an associated cost. So, cost is a direct measure and hence this terminology, this particular process, this particular tool is very effective in calculating in understanding the sustainability.

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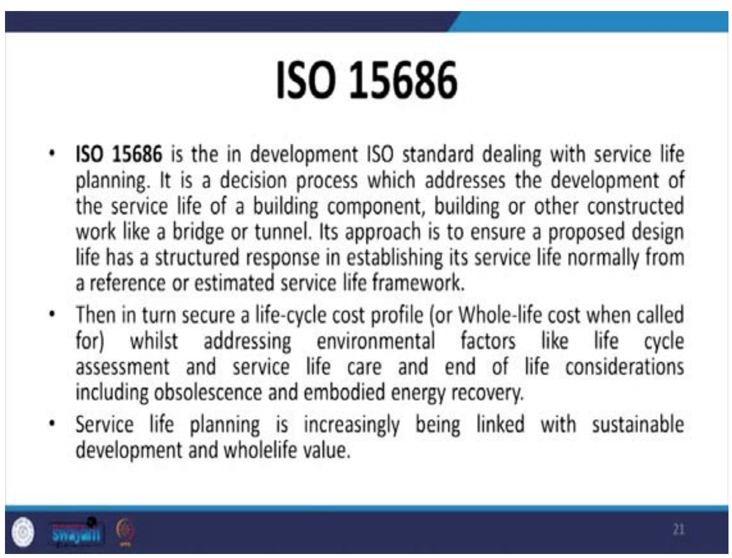

Besides ISO 14041, there is a new code which is in the process of development which is ISO 15686 which is the standard which is dealing with the service life planning. Now, here we are looking at a code where it is impacting the decision process, how the development of the service life of a building component or any other module for that matter is taking place.

This is still under development and we are looking at the entire life cycle cost profile, we are looking at the entire life cycle assessment, but we are also looking at the policy and decision side of it which is slightly ahead of 14041. The next tool is designed for the environment. It is a design approach which is to reduce the overall human health and environmental impact of a product.

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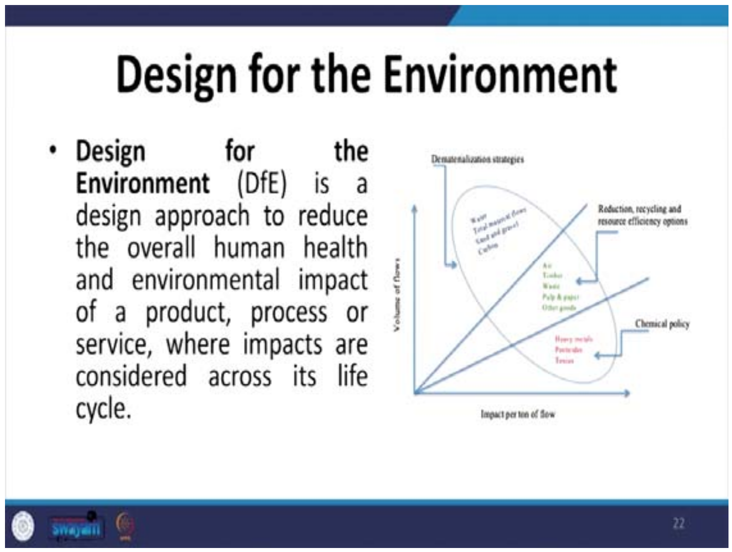

So, so far in the carbon footprint and through life cycle assessment and analysis approach, we were mainly looking at the environmental impact, ecological impact of the product or process. However, through this approach we are also looking at the impact on human health and the overall impact on human health as and environmental impacts as well throughout the life cycle of the product.

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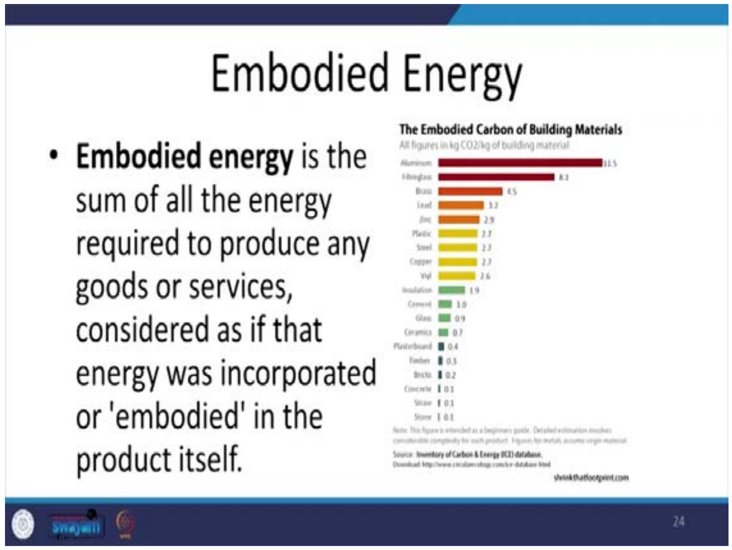

The next terminology which we are commonly using is embodied energy. Now, embodied energy is the sum of all the energy required to produce any product or carry out a process. It is mainly use for products, and unlike life cycle energy where we are taking into account the energy which is being consumed for all the associated processes while manufacturing a product. Here we are looking at the energy only for the production of a particular material, a very linear process.

So, for example, suppose we have we are talking about the embodied energy of cement as a material, so we will be looking at the raw material extraction the amount of energy which is consumed for the extraction of the raw material, its transportation to the factory, the amount of energy which is required to process this material, and then packing it, and making it ready for transporting it to the consumer and then the consumer uses it. So, the energy which is going in each of these components is counted. But in embodied energy we are not accounting for any energy which is used to mitigate the environmental impact.

However, when we are looking at life cycle energy analysis life cycle energy ~~approach~~approach, we are also looking at the associated environmental impacts from an energy point of view. So, for example, suppose we have a lot of heat being dissipated, so the amount of energy which is further required to capture it or utilize it is also accounted for an life cycle energy approach, but not in embodied energy approach.

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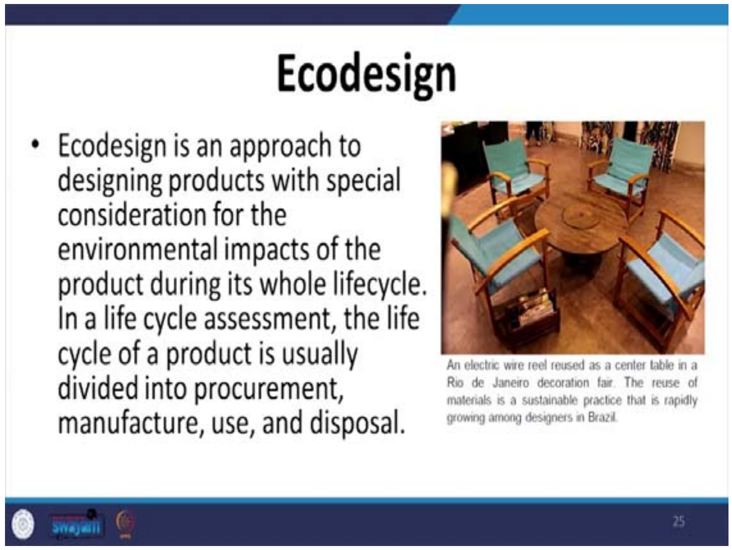

The next approach, the next tool is ~~ecodesign~~eco-design and it is an approach to design products with special consideration for environmental impacts of the product during its entire life cycle. Now, many of these terminologies that we are talking about, they are synonymous, they are interrelated. It is a new concept this ~~ecodesign~~eco-design and another concept which is quite similar to this and very closely associated is environmental effect analysis.

Here we are taking into account the wishes, the requirements of the customers consumers, we are also talking about the legal and market requirements. So, we are not just looking at environment separately in isolation, but we are looking at the social aspect of it. We are looking at the manufacturing process along with the requirement of the market and the legal requirements as well.

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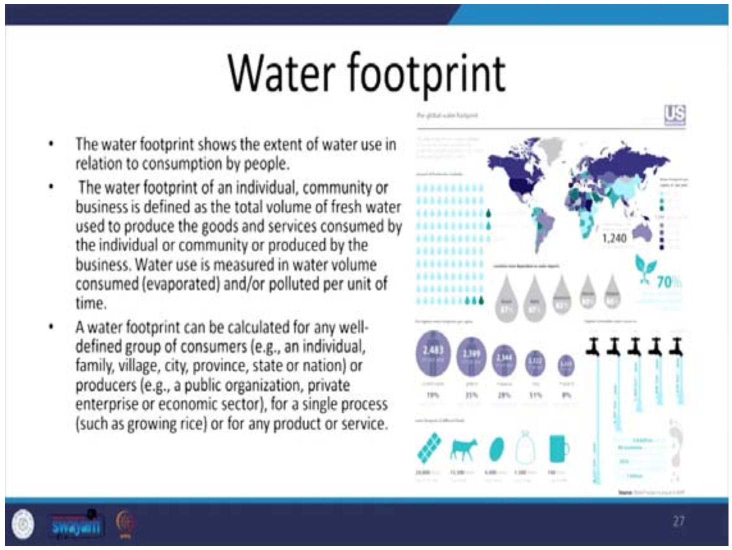

Just like we have carbon footprint, we also have terminology which we call as water footprint. So, for each of the product and process we consume water and how much is that water footprint is calculated, in exactly the same manner as we calculate the carbon footprint or environmental footprint, ecological footprint.

So, it can be water footprint can be calculated by adding up the water volume consumed or polluted per unit of time. So, we are not just looking at the water consumed, but we are also looking at the water which is polluted through the process. This is water footprint.

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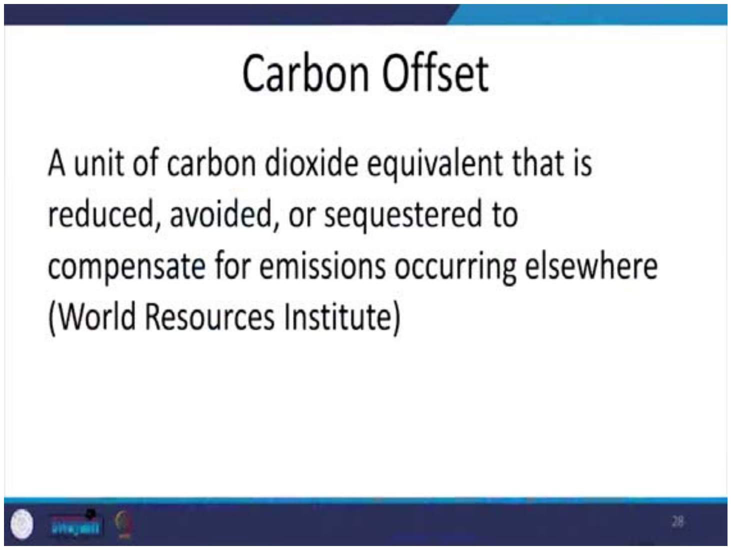

Now, another terminology which is used is carbon offset or carbon sequestration. So, for 1 unit of carbon dioxide equivalent that is reduced or avoided or sequestered. Sequestered implies which is captured back to compensate for emissions occurring anywhere, elsewhere is what carbon sequestration or carbon offset is.

Now, there are different strategies within the design which help us to offset this carbon emission or sequester the carbon the best to be plantation of trees. So, leaving land for planting trees or greenery is a very strong robust method off carbon offsetting or carbon sequestration.

All of you must have heard about the concept of ozone depletion. Now, this is destruction of the earth's ozone layer by the photolytic breakdown of chlorine or bromine containing compounds which catalytically decomposed ozone molecules.

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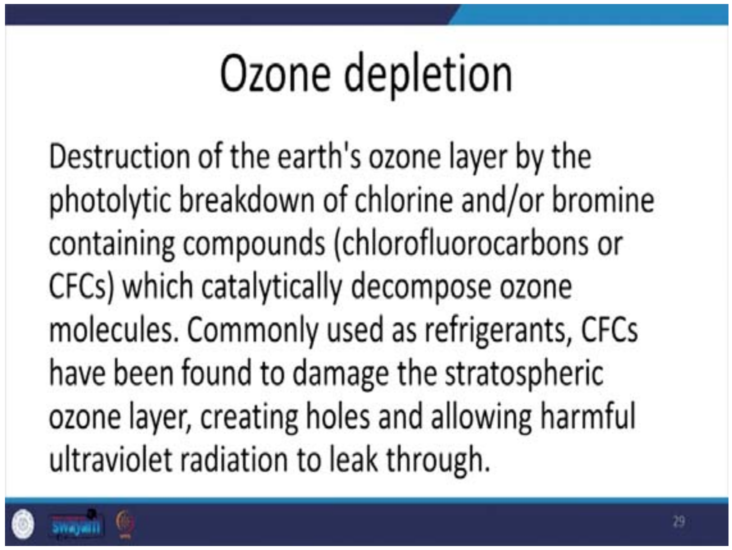

So, there was a lot of discussion, in the previous lectures, we have looked at how ozone depletion led to the successful assigning of Montreal Protocol and how it led to banning of CFCs, CFC ~~ah compounds which~~compounds which is for ozone for reducing the ozone depletion.

Now, when we are talking about all these terminologies, we have to directly look at what is the implication, what is the, how do we understand each of this terminology in the building context. So, when we are looking at say carbon footprint or ozone depletion or carbon sequestration, we have to look for strategies which can be employed in building, buildings which one say do not deplete ozone or which have lesser global warming potential or which have lesser carbon footprint. So, we have to know about each of these materials, we have to understand them and then make an informed choice, informed decision.

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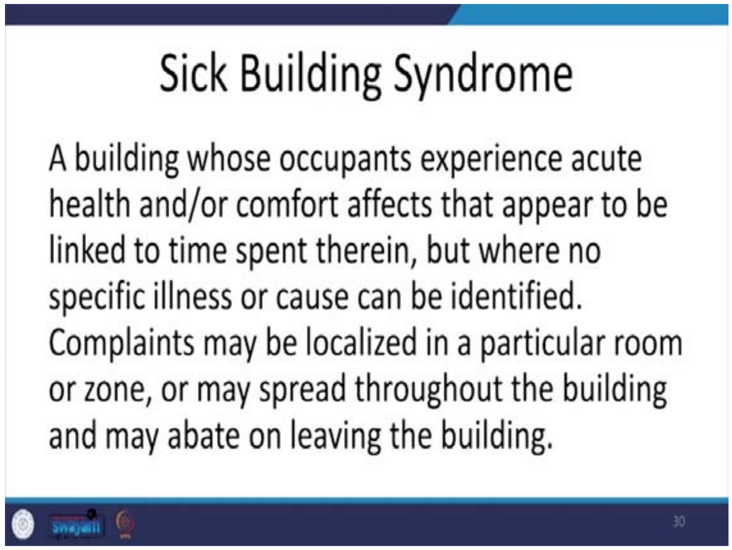

Another very important terminology that we often use is of sick building syndrome. Many of you might have heard about this sick building syndrome which is which is very commonly discussed in public, in media. These are buildings where the occupants they experience acute health or comfort affects and they are not associated with any specific illness or cause, it cannot be identified yet.

People when they spend long hours or substantial duration insight some buildings such buildings, this is called as sick building syndrome. Now, this may be because of a lot of various reasons, but primarily all of that can be summed up where the indoor environment quality is not good.

Now, indoor environment quality may seem a very tangible term, where we may be monitoring? What is the carbon dioxide level? W~~w~~e may be monitoring w~~? W~~hat is the temperature? What is the air movement? How much is the fresh air coming in and all that. But besides ~~that~~that, there are a lot of psychological reasons as well, where people are all the time enclosed within the buildings, they do not have visual connect with the nature outside the greenery outside.

So, they emotionally psychologically they become sick. So, that is also another type of sickness. So, all this is clubbed within the sick building syndrome and people do not feel comfortable or healthy staying in these buildings.

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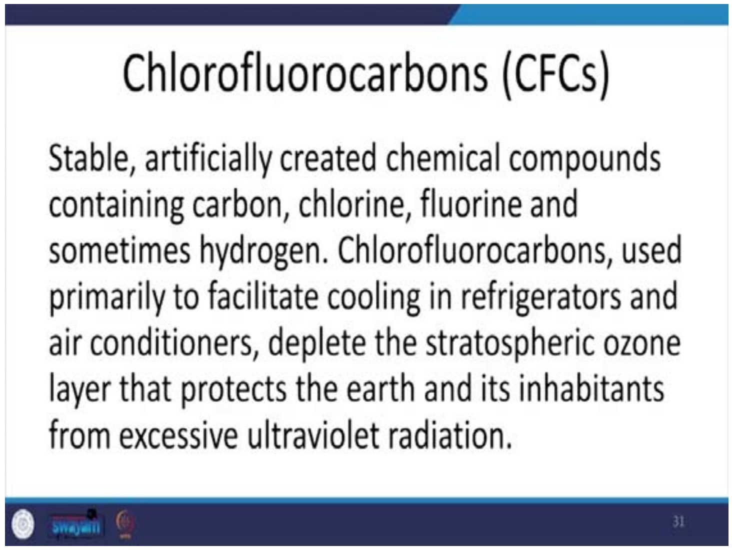

We have already talked about these chlorofluorocarbons. These are the chemical compounds which are responsible for depleting the ozone layer. So, as architects and as responsible architects who are aiming to create sustainable buildings, we have to know what are the compounds which can be classified as CFCs, what is there ODP Ozone Depleting Potential and what is that GWP and use the products which have less of such CFCs or which have less of GWP and ODP.

A lot of research is being carried out across the world to look for new materials, new compounds which can be used as a refrigerants and which have both low GWP and low ODP. Often so far it has been found that compounds which have high ODP have low GWP and which have high GWP they have low ODP. So, the research is on for finding out new substitutes, new compounds which have both low ODP and low GWP. Now, CFCs are largely used in refrigerants, as refrigerants.

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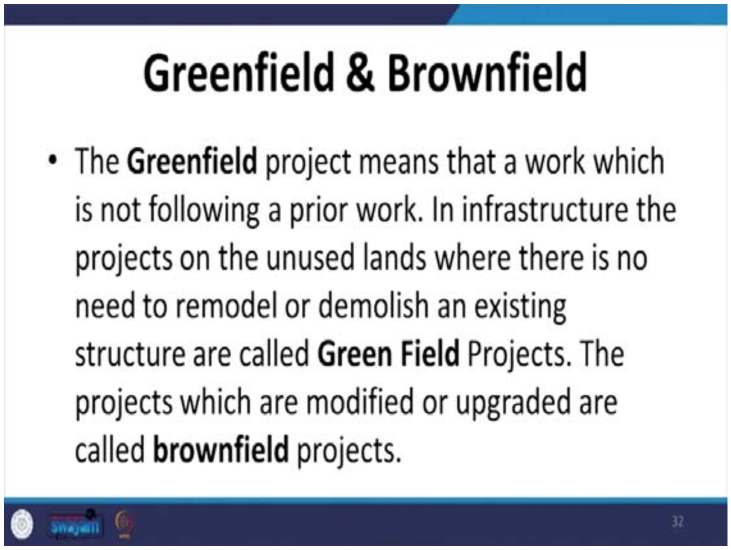

The next terminology, which is related to sustainable buildings, is Greenfield and Brownfield. Greenfield project implies that there is no demolishing of an existing structure required where the land is open, barren; it has not been previously used for any other purpose. So, it is actually a good for fertile land which can be used for anything. That is a Green Field project.

On the other hand, the Brownfield project is a project where we are modifying or upgrading an existing project or may be demolishing and then reconstructing where the land, the project site has already been used for some things. So, that is a Brownfield project. So, the quality, the ecological quality of the site has already been altered that is a Brownfield project. So, it is preferred to develop on a Brownfield than a Greenfield, because Greenfield is a good site.

Then another common terminology that we use in these green buildings and sustainable buildings quite often is Energy Performance Index, EPI.

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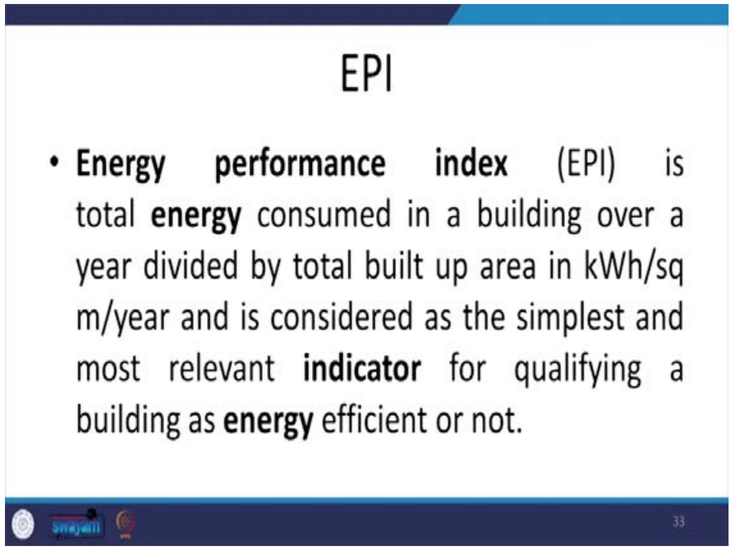

And it is the total energy consumed in a building over a year divided by the total built up area and the unit is kilowatt hour per square meter per year and it is the simplest and the most relevant indicator for qualifying building as energy efficient or not. If you look at the bureau of energy efficiency website in India, so they have BEE star rating for buildings and that is actually the numbers which are given are actually EPI numbers, energy performance index numbers and that talks about how much energy in kilowatt hours per square meter per year is consumed by a building and that is a very good measure.

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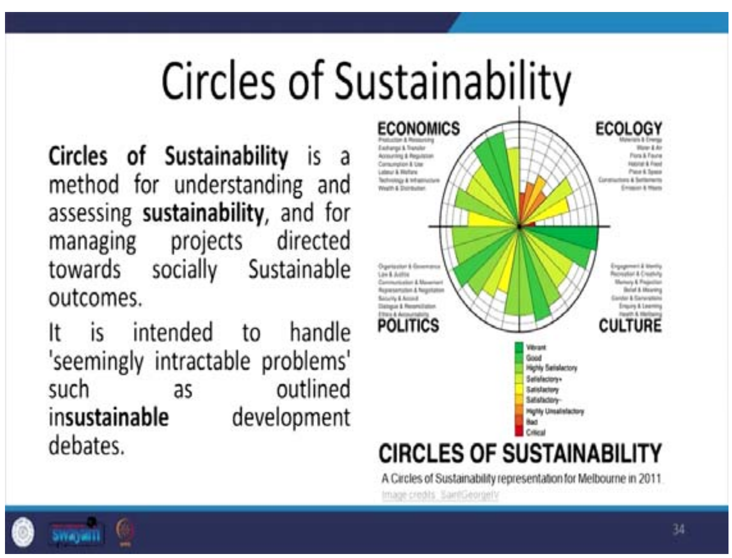

Now, this is the last terminology that I will discuss in this lecture and it is beyond buildings. It is at the level of city, but I think it is relevant here because and this terminology is called circles of sustainability. It is a very comprehensive method for understanding and assessing sustainability and all the aspects of sustainability so, not just environment.

So, when we were talking about all these terminologies which are related to ~~buildings~~buildings, we see that we are largely focusing on environment because that is more tangible and easily quantifiable. However, when we are looking at these circles of sustainability and talking about the cities at large, we are looking at culture, politics and economics along with the ecology.

So, all the different concepts which can be clubbed understood within ~~the these~~these domains of economics, politics, culture and ecology, they will be understood, they will be ranked, rated, measured and put on in one graph which is understood as circles of sustainability. And it is intended to handle the seemingly intractable problems.

For example, say engagement and identity within a quantifiable manner through this approach which is called circles of sustainability. I will close my lecture today, and we will meet up for the next lecture for this ongoing online course on Sustainable Architecture.

Thank you.