Carbon Accounting and Sustainable Designs in Product Lifecycle Management

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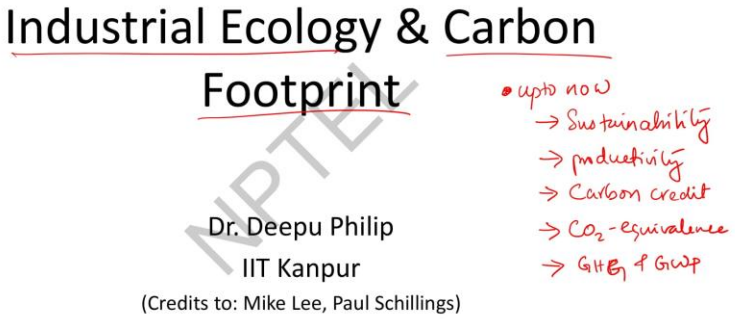
Week 02

Lecture9

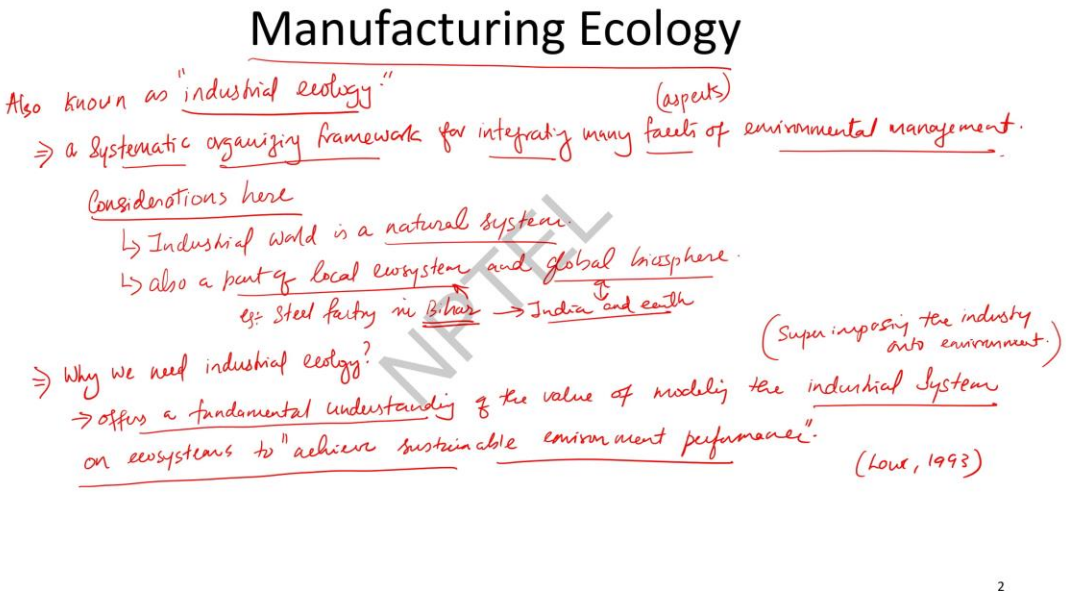
Industrial Ecology & Carbon Footprint

Good afternoon, everyone. So, I am Prof. Deepu Philip from IIT Kanpur, and we are here today to listen to yet another session of the course, NPTEL MOOC's course titled Carbon Accounting and Sustainable Design in Product Lifecycle Management. Along with me, Dr. Amandeep Singh Oberoi and Dr. Prabal Pratap Singh are co-teaching this course.



And today we are going to study the most important concept, the transition concept today, which is called as industrial ecology and carbon footprint.

So, up to now, we have studied Sustainability, Productivity, then we have also seen what is a Carbon Credit. We also saw, what is called as CO2 equivalence. We saw, what is called as GHG and GWP, that is GHG greenhouse gases and GWP global warming potential. We have seen these major concepts and today we are going to take it to the next level.



So, without further delay, let us first go through what is called Manufacturing Ecology, okay. Manufacturing ecology is also known as, it is also known as Industrial Ecology, okay. This is another name for it, industrial ecology, okay. So, the, what is it? Okay. So, how do we define it? It is a systematic process, organizing framework.

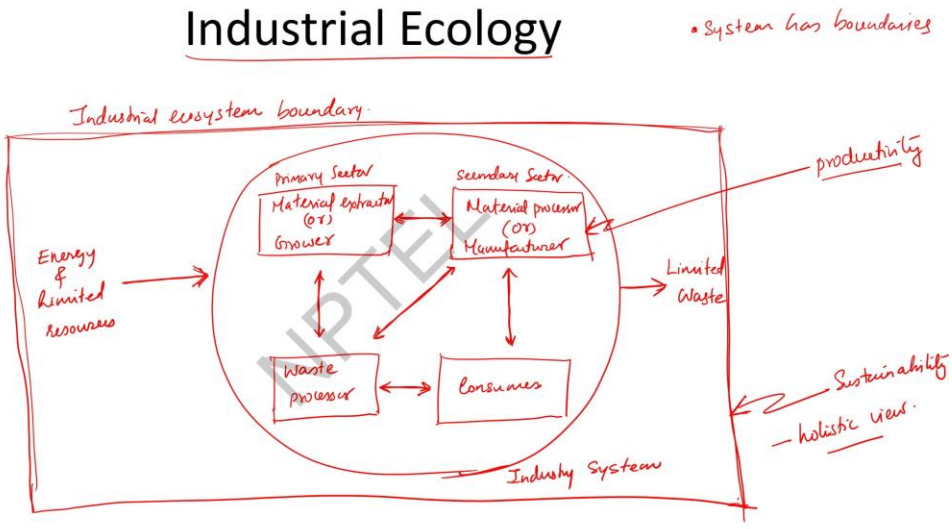
It's a systematic organizing framework for integrating many facets of environmental management. So, it is a systematic and organizing framework that integrates many aspects. It is also another way to say, it is aspects of environmental management. So, the considerations here are industrial world is a natural system, okay. Second one is also a part of local ecosystem and global biosphere, so, it is a natural system.

Natural system means there is all aspects, inputs, outputs, etc, all are there, it is an interacting system, but it is also part of the local ecosystem and it is part of a global biosphere. So, if you have a factory, that is in, example, steel factory in Bihar, for example, okay. So, Bihar is part of the local ecosystem, called Bihar, which is a local ecosystem. And then, it is part of the ecosystem of India and Earth.

That is the global ecosystem. So, we have to consider both aspects. So, the question is, why we need industrial ecology? Why do we need this? Because it offers a fundamental understanding of the value of modeling the industrial system, the industrial system, ecosystems or ecological system, to achieve sustainable environment performance.

This explanation was given by Love in 1993. So, what we are talking here is, it offers a fundamental understanding. So, how do you superimpose? The idea is that superimposing the industrial ecosystem on to environment, instead of ecology, let us call it as environment. If you superimpose the industry on to the environment, then what are the issues that we have, so that we can address those issues to achieve sustainable environmental performance.

We already studied, what is sustainability. So, the critical part is how do we achieve sustainable environment performance. So, that is the main aspects of the system.



Now, let us see what is this Industrial Ecology is all about, how do you model this? So, one way to think about it is, we first create what you call as every system.

So, one aspect is system has boundaries, so, let us call this as the industrial ecosystem, okay. So that is what this whole thing is about, industrial ecosystem boundary, right. Now in this industrial ecosystem we have, what is the industrial? So, one way to think about is, we have an industry, okay, so in industry you have something called one box, okay, which is called Material Extractor or Grower, okay. Somebody who extracts the material from the earth or somebody who grows it. That's the primary industry.

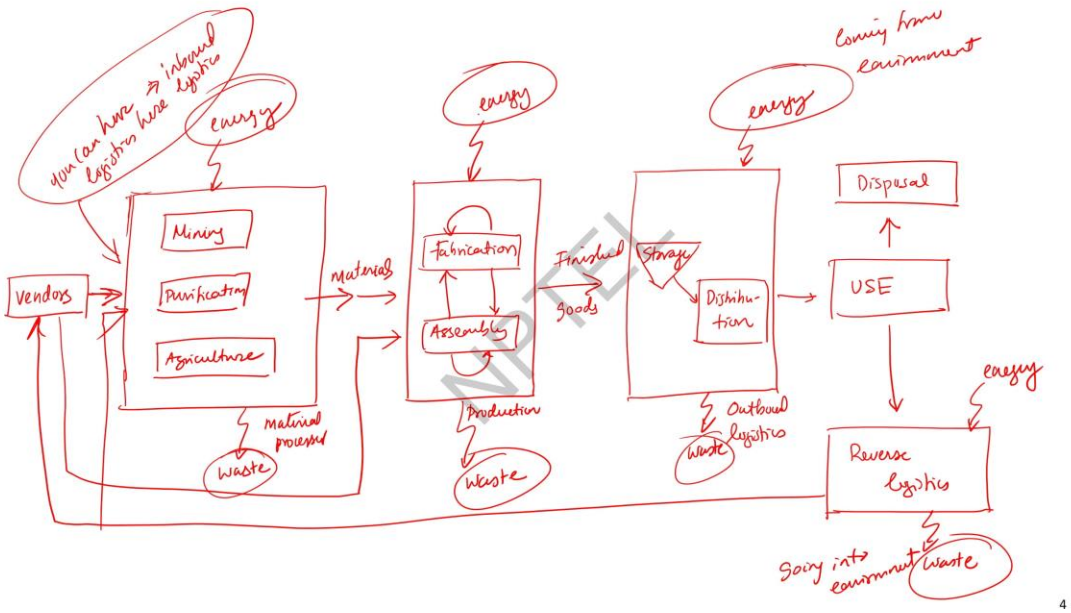
One way to think about this is the primary sector, okay. Then comes the second one, which we call as material, processor or manufacturer. So, there is a relationship between both of them. So, this is the secondary sector. The primary sector is you are dealing with the environment.

And secondary sector is you are taking it to a factory. And then the third one is, you have the third aspect is, what you call as consumer, okay. The consumer interacts with the manufacturer in this particular fashion, takes the final goods and do it. Then there is a third one which is called as a Waste processor. So, the consumer sensibly used the good to the waste processor.

And then the waste processor has an interaction back between what we call as the material extractor or drawer. And there is also another possibility of an interaction between the secondary sector, the manufacturer directly with the waste processor for collecting some aspects. So, this you can think about as the industrial, okay, the industry system. Now, you have also something called as energy and limited resources, okay. These go into the industry system.

The energy comes from the environment or the government produces the electricity and supplies it to the industry guy. And then you have the limited waste that is expelled out of the factory to the environment. So, most of the time, the productivity, this is where the productivity is focused on, it is on the manufacturing side. That is where productivity. Whereas, sustainability is focused here.

So, sustainability is more of a holistic view, okay, so that is what we actually think about as the industrial ecology in this regard. Now further narrowing this down in a different way.



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You can also think about the one way to imagine this is, you have vendors in one side and then in the vendors, you have basically like in my opinion you have the the material processor, okay. So, these vendors supply lot of those things to the material processor and the material processor takes energy onto this, and then there is waste coming out of this, and then, output of materials and that output goes into next one which is the production or manufacturing, you have something called fabrication and then you have assembly.

So, Fabrication is making individual parts and it is going back and forth between both right and then both of them also have their own. Sometimes you keep on doing that fabrication there itself, there also you have energy and there also you have waste like this, and then also some of the times these vendors who are actually supplying here they may also do a supply here as well for something, that kind of a thing. So, they may bypass the material processor. So, the material processor might be something like, there are activities that you can put it as mining, purification, agriculture, etc.

So, all of them might be providing you with the different type of materials or other raw materials to go into the assembly process. And then from here again, it goes into finished goods, okay. This goes into what he called us in another way to think about it is outbound goods logistics, okay, so this is storage, so we have something called storage. Storage is denoted by a triangle, usually in this one then you have also something called distribution

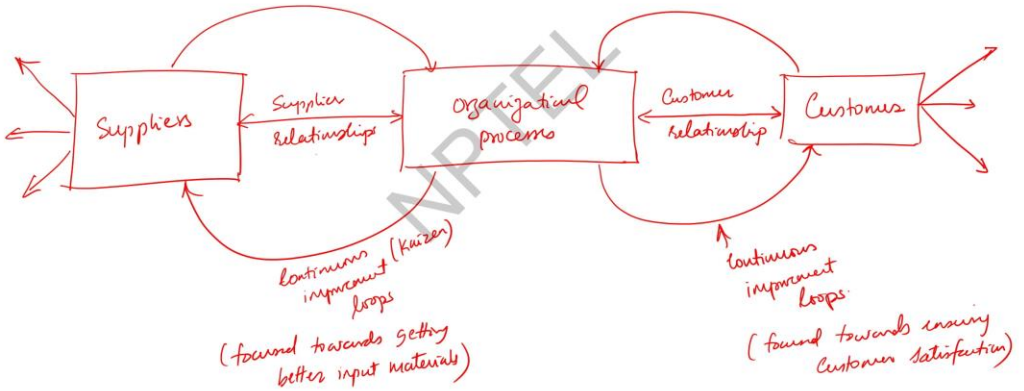
etc, like this, okay. So, this is part of this, once the distribution is done then you have something called use, which is done by the customer, right.

Sometimes after the use it may go to disposal, it may go into the, some part of it may go into the environment, some part times we will go into what you call as reverse logistics. So, some aspects may get recycled, it gets reverse logistics and it may go back to the vendor or it may go back to the preprocessor. And all these kinds of things, here also the reverse logistics, you have energy being used, okay, and you may have waste here, packaging waste and that kind of stuff. Here also you have waste. So, you can see that in all places, you are gaining, getting this energy.

It's all coming from the environment, and this is coming from all these waste that we talk about, they are all going into environment. I drew this diagram just to make sure that you guys understand that in each step. We saw this here as a very large system, but if you take each step into small small parts, you can very clearly see that each one of them, even though they have their own boundaries and other kind of things. They continue to take each step, takes energy and produces waste and it goes into the local environment, so that's one, other thing that you need to understand, then based on which we also extend to like what we say here is the outbound logistics, what we call, sometimes here also you can have logistics in between, okay.

You can have logistics here, okay. That is inbound logistics, but very rarely people do this because lot of the time this primary activity happen, where it is, so the agriculture happen where the party field is and you don't carry the field around everywhere. So, this also is possible for you.

Supply Chain Management



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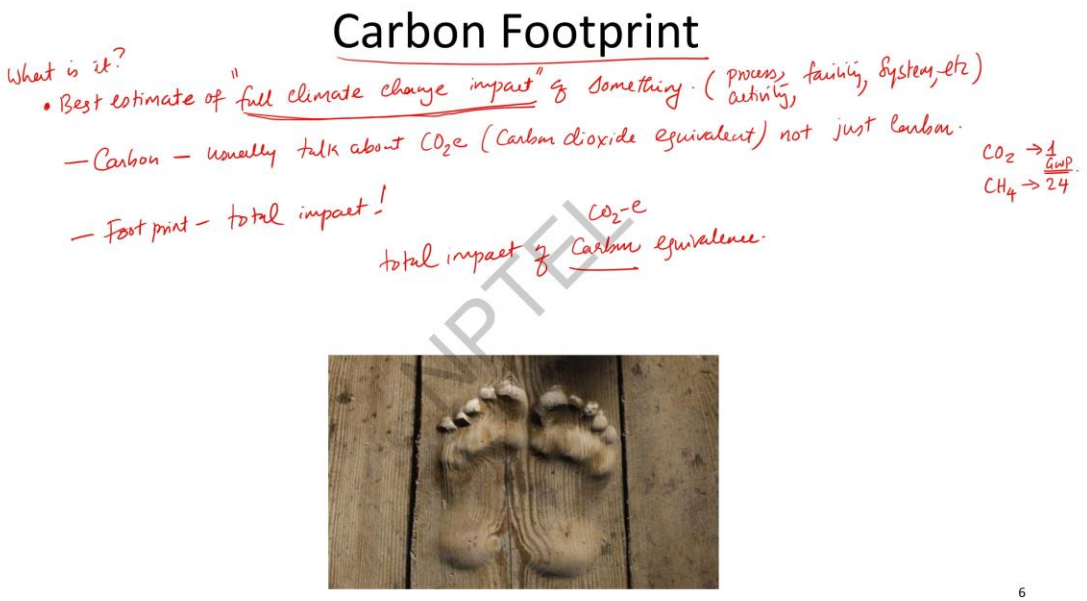
So, the Supply Chain, if you think about it that way, you have something like suppliers and you have the organizational processes, and then you have the customer, okay. So, the customer and the organization processes, in an organization process to a large extent is in a way in this case is manufacturing, right, so this is called as customer relationship, because the customer is buying the finished good from the organization that is making it.

So, what happens is sometimes the customer gives feedback and the feedback goes back to the customer. So, this is what we call as continuous improvement process, loops, the Kaizen loops. And customer may do whatever he want or she wants with that product. They may use it, they may dispose it, they may give it back to someone else. And same way, you have what you call as, to the supplier, this is also known as continuous improvement loops, also known as Kaizen loops. okay.

So, for the supplier also, the manufacturer will tell you or tell the supplier, what is good, what is not working and that kind of things and using which the supplier will provide better materials. So, this relationship, which is called as supplier relationships. So, the organizer and the supplier maintains a relationship which is called as a supplier relationship and they have their own kaizen loops continuous. So, this is focused towards getting better input materials. That is what the kaizen loop of the supplier organization process happens.

This is focused towards ensuring customer satisfaction. So, the kaizen loop on the customer organization side is focused more towards ensuring customer satisfaction.



So, now let us get into the concept of what we call as Carbon Footprint. Given you the ugly stuff of a footprint, but what it is and why do we need to know about this? So, it is in a way, it is the best estimate. What is it? Okay.

What is Carbon Footprint? It is the best estimate of full climate change impact of something. It is the best estimate of the full climate change impact. The key word is full climate change impact. You are not talking about the smaller area.

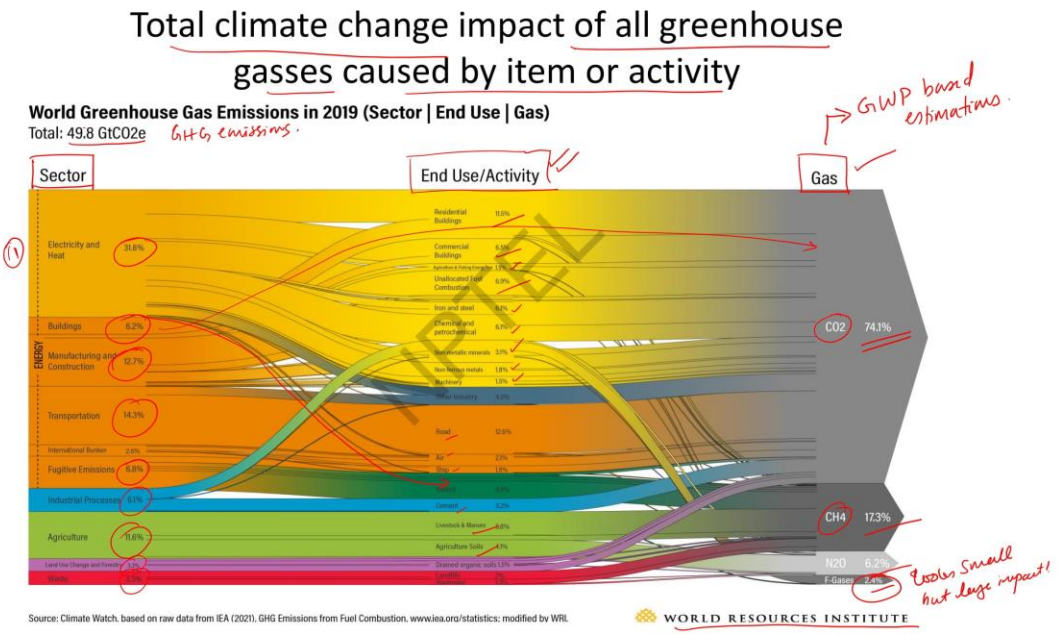
You are talking about the global climate change of something. What are the something? Something can be a process, activity, facility, system, etc, all of these things are part of that. All of these things are part of that. So, you have something, a process or an activity or a facility or a system etc, and you want to estimate the full climate change impact, then carbon footprint is the best thing to do, okay.

And you want to estimate the full climate change impact, then carbon footprint is the best thing to do, okay. So, I said earlier is carbon, we usually talk about CO_2e, I mentioned this earlier. That's called carbon footprint, dioxide equivalent, okay. Not just carbon, because I mentioned to you guys earlier that CO_2 and CH_4 (methane).

This is the reference gas with one. Methane was, I think it was 24 or something like that. So, we talked about how this GWP can be used to calculate the carbon equivalent. And so, we are using CO_2e, not just carbon, right. And what is footprint?

Footprint is the total impact. That is what we call as the footprint, so, carbon footprint means the total impact of carbon. So, the total impact of carbon equivalent or equivalence, when I say carbon equivalence, I am talking about CO2e, so you are converting everything into the reference gas and using that and then calculating what is the carbon impact or carbon footprint of the total thing. Now, let us talk about this is just a calculation or showing impact of carbon equivalent or equivalence, when I say carbon equivalence, I am talking about CO2e.

So, you are converting everything into the reference gas and using that and then calculating what is the carbon impact or carbon footprint of the total thing.



Now let us talk about, this is just a calculation or showing something. So, let us talk about the Total climate change impact of all greenhouse gases caused by an item or an activity, okay. So, here you have a sector, different sector, industry sector and here you have gas, different type of gas and what is the activity associated with that sector is written here.

So, the sector here is, if you look into this, this is electricity and heat is the first sector, a majority of that,

A majority of that, this is, we can say the 31.8%, okay. So, if you take the world greenhouse gas emissions, GHG emissions, okay. So, this is the GHG emissions, okay. In 2019, okay, it is 49.8 gigatons of carbon dioxide, gigatons is a billion-ton, GT is gigatons, stands for gigatons. Gigatons is a billion ton.

GT is gigatons, stands for gigatons. About 50 gigatons of carbon dioxide equivalent in 2019. This was the time this graph was updated, the last point. So, electricity and heat, about 32% of the total thing, of which 11% is for the residential, 6.5% is for the commercial buildings, agriculture and fishing is 1.9%, which is this unallocated fuel combustion is about 6.5%. Iron and steel industry uses 6.1%.

Chemical and petrochemicals 6.1%. Non-metallic minerals 3.1%. Non-ferrous metals 1.8%. Machinery 1.5%, of which majority of this, if you look into this, this diagram shows that majority of it is associated with carbon dioxide, CO2. Of which majority of this, if you look into this, this diagram shows that majority of it is associated with carbon dioxide, CO2.

Very little of it, you can see some sections, very little of it is actually going to methane and nitrous oxide. So, that is the electricity sector. Then, you have the building sector, okay. Building sector also has a lot of this. so, you can see each sector. This sector has, you can see one portion of this is going to carbon dioxide, whereas, some sector of it, you can see that this is actually going to the, it is actually coming to, you can see that it is coming to the methane, CH4 aspect.

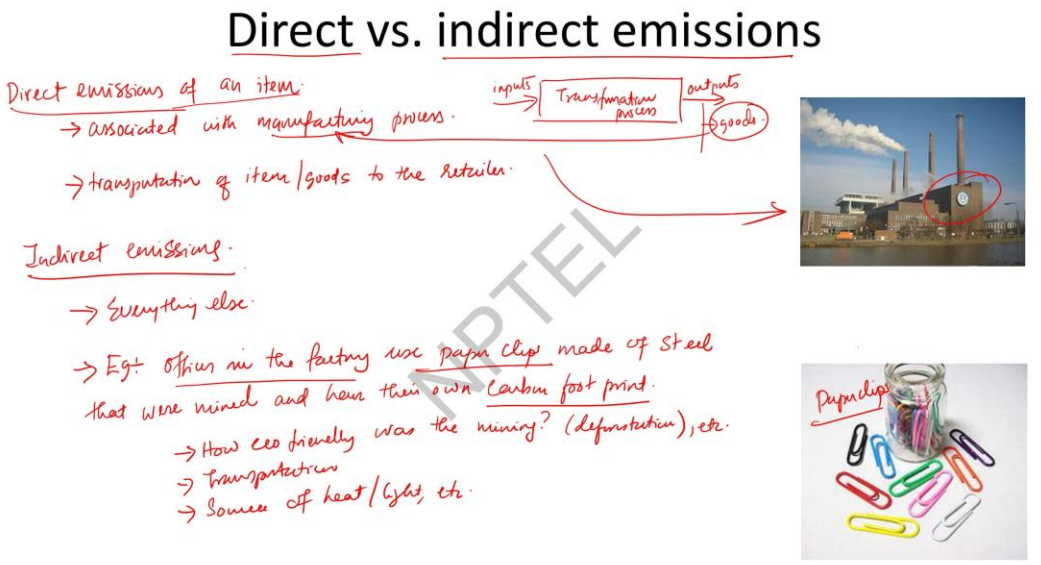
So, by the type of gas also we can calculate. So, majority, 74.1% of it is carbon dioxide. Then next is 17.3 is methane. And then the nitrous oxide into O is 6.2%. And F gases, F gases is the, we have mentioned about methane, okay. SF6 and those kinds of things, that is 2.4%, okay.

SF6 and those kinds of things, that is 2.4%. But remember, the SF6 was 24,000 times more potent than CO2. So, the 2.4%, even though it looks small, but large impact, okay, that is the one aspect of it, and similarly, manufacturing products and construction, okay, that is the one aspect of it. And similarly, manufacturing products and construction. You can see that it is using 12.7%.

Transportation is using 14.3%. Then, fugitive emissions is 6.8%. Industrial process is 6.1%. Agriculture is about 12%. Land use and forestry is 3.3%.

Waste is 3.3%. So, across different sectors, how is the outlive, the energy is there, and then, where is it actually going to? When you talk about transportation, it is going to road, air, shape, etc. Then you can see that the industrial process is cement, which is one of the major consumers of this one, and then in agriculture, you can say livestock and manure consume some part of it, and agriculture and soil consumes the remaining of it.

So, this kind of a thing, which was created by the World Resource Institute, allows us to now monitor the, by sector-wise, the energy usage, which activity it is being used for, and what gas it is actually emitting. So, this allows us to, so knowing this gas allows us to do GWP based estimations, okay. GWP is as I told you global warming potential based estimations.



So, now let us talk about the major concept called Direct versus Indirect emissions. So, what are these direct emissions of an item? This is critical for us. First, we need to find out. So, this is associated with manufacturing process. What is manufacturing process? I mentioned to you guys earlier, you have inputs and you have a transformation process, and you have outputs.

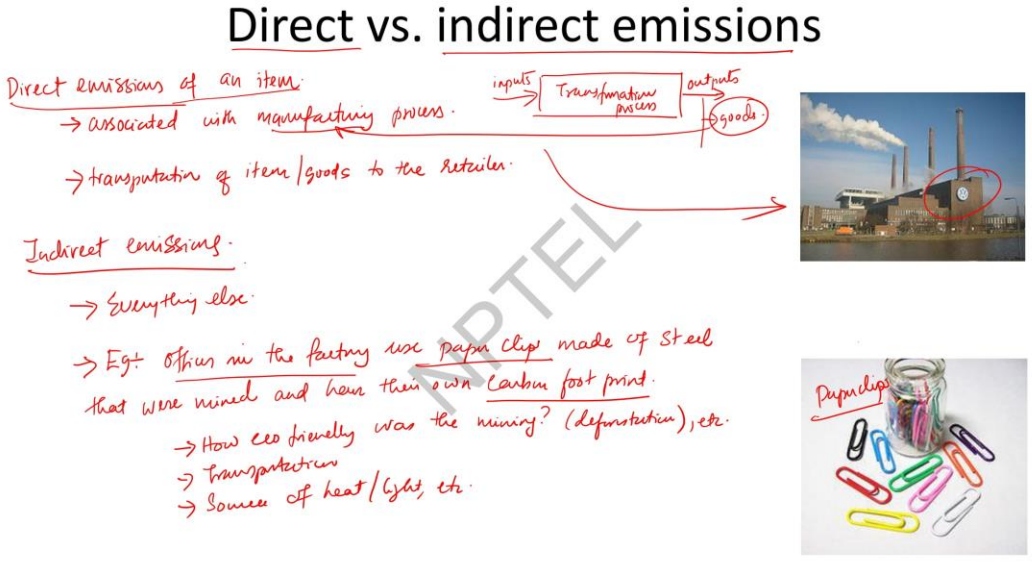
So, if the output is goods, physical goods, if that is so, then that is called as the manufacturing process. If it is a physical good, the transformation process becomes manufacturing process, right. then also other one is transportation of item or goods to the retailer. That also is part of the direct emissions of the system. Now, the second one is indirect emissions.

What are indirect emissions? So, the simplest way to understand it is everything else. So, the direct emissions, we can think about it as, here is a Volkswagen factory. So direct emissions are associated with this, the factory. So here is an example.

I have given an image of paper clips. Here is paper clips. Why did I do this? Let's take an example, officers in the factory use paper clips made of steel. Let's say made of steel that were mined and have their own carbon footprint, okay.

So, this paper clip, even though it appears to be simple, but it was mined. So, it was like, how eco-friendly was the mining? Okay. Was there any deforestation? Okay. Large amount of blasting, etc, okay. Transportation, the source of heat and light etc.

So, all of these things together determines how eco-friendly or what is the carbon footprint of that particular paper clip. So then, because that paper clip is used by the factory office, offices in the factory, that accounts for indirect emissions.



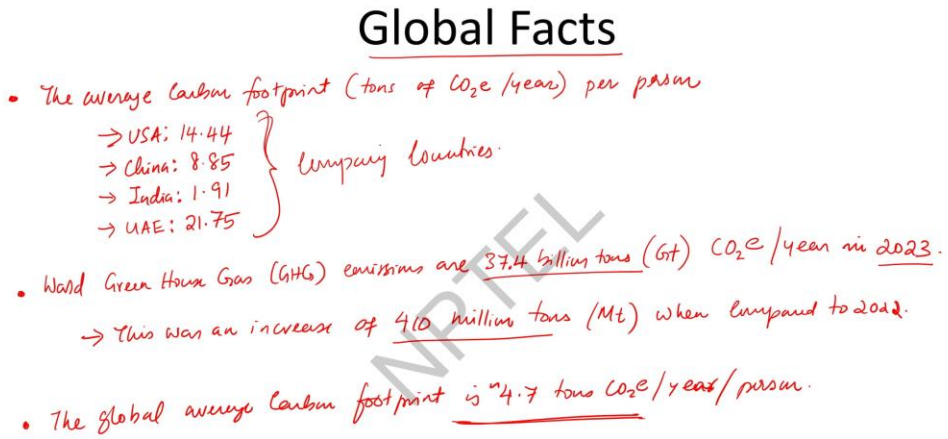
Now, let us talk about, or let me try to give you some context of the numbers. So, all of you guys had some issue when I talked about the burning of the fuel. So, this is, you can see, this is a pea, okay, chickpea.

This is also known as garbanzo, okay, garbanzo beans or kabuli chana in Indian terms, Indian language, okay. So, if I burn, okay, as we mentioned earlier, one gram of CO2e would be produced if we burn a pea-sized blob of gasoline, okay. I wanted you guys to remember that, one gram. So, this 1 gram is associated with, if you burn one of this, this much is, will give you 1-gram equivalents of carbon dioxide.

Now, next one is 1 kilogram. Let me now scale to 1 kilogram of CO2e, carbon dioxide equivalent, okay, would be produced if we burn 2 cups of gasoline, okay. This 1 kilogram is this, okay, or let me put it this way, these are the. this is 1 cup, this, okay. Or let me put it this way, these are the, this is 1 cup. So, 2 cups, if you take this much of gasoline, burn it, then you will get 1 kilogram of carbon dioxide decollete.

Now, the third one is 1 ton of CO2e would be produced if we burn 60 gallons of gasoline. So, what is 60 gallons of gasoline? Everybody had this question. The answer to that is, imagine a fish tank, a normal home aquarium. They are typically 60 gallons.

So, if you take a home aquarium full of gasoline and burn it, then you produce 1 ton of carbon dioxide equivalents. So, now you may have an understanding of what we talk about these numbers, okay. We mentioned it in the previous class, but now you can actually get a physical sense of what we are talking about, okay.



Now, let us take some Global facts as part of this, okay. The Global facts is, some of the numbers is, these numbers will help you to put things into perspective.

The average, the average carbon footprint, okay, that is tons of CO_2e per year. Average carbon footprint is per person, okay, per individual that we are looking at let us take USA, first USA is about 14.44 tons of carbon dioxide equivalent per year, okay. China now the largest emitter is 8.85, it is increasing while USA been reducing for the last 2-3 years, India we say, we are a big polluting country, but our per person emission is 1.91 tons of carbon dioxide. Then I also want to put something else into perspective.

One of the most everybody now talks about UAE, Dubai and etc. There they are also growing like crazy, so that is 21.75. So, this is the average carbon footprint per person that is tons of carbon dioxide per year. Now, another data you need to know is world greenhouse gas, GHG, okay, emissions are 37.4 billion tons, okay. The billion tons is also known as GT, which is gigatons, okay.

Billion tons of carbon CO_2e, the carbon dioxide equivalent per year in 2023, okay. In 2023, the total emissions is 37.4 billion tons of carbon dioxide, okay. This was an increase of 410 tons, that's empty. So, when compared to 2022. So, if we compare with 2022, then the increase was 410 million tons. The 2023 emissions is 37.4 billion tons or gigatons.

Then, the global average carbon footprint is approximately 4.7 tons of CO_2e per year per person. So, the globally, if you take all countries across and we calculate it, it's about 4.7 tons of carbon dioxide equivalent per year per person. So, with these numbers, what we will do today is, so that completes our current presentation, which gives you a preamble of, how the carbon footprint, and how you can use this carbon footprint to compare different countries, different processes across the globally, who is doing good, who is doing bad, whether we are increasing our emissions, decreasing our emissions. So, carbon footprint actually gives you one very important comprehensive way of comparing different type of emission.

So, for example if you look into this slide, you can see that, we are now comparing in this case, comparing countries, okay. So, across the globe, every country now have a carbon footprint. And we can say who is emitting more, who is emitting less, etc, like that. So, with all these things, we can now say that we have the foundations or the fundamentals of, what is carbon footprint, and how it is required, or why it is important, and why we need to take this forward for doing a global comparison. Thank you for your patient hearing.

We will continue in the next class, how to calculate this carbon footprint of simple systems. Thank you.