Carbon Accounting and Sustainable Designs in Product Lifecycle Management

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Week 08

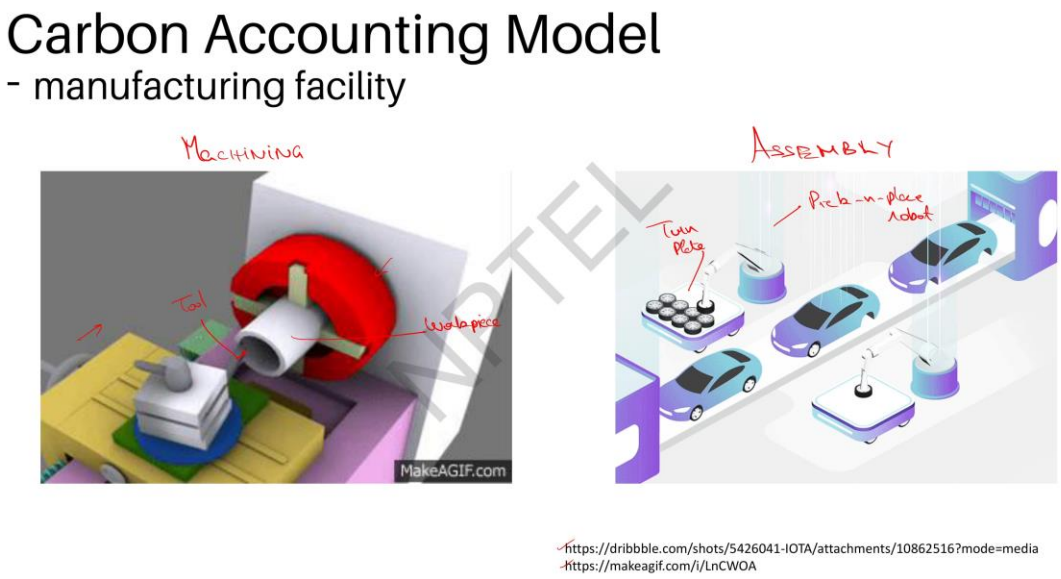
Lecture 35

Carbon Accounting Model (Part-2)

Welcome to the second lecture of week 8. We are in the course Carbon Accounting and Sustainable Designs in Product Lifecycle Management. And we are discussing carbon accounting models in this course. I am Dr. Amandeep Singh oberoi from IIT Kanpur. Along with me, we have Professor Deepu Philip and Dr. Prabal Pratap Singh who are teaching this course.

And in the carbon accounting model, I am talking about a manufacturing facility. I will talk about all the layers, part, product, facility and the equipment layer. We have discussed about the layers in detail in the last lecture and we have also discussed about the components in these layers. We will try to now see mathematical models, the quantitative models for these layers. Also, we tried to see that carbon emission sources are there and different processes are there.

For example, machining, forging, sand casting and assembly. And what are the parameters which are prevalent in these processes and which of them are not? For example, non-electric energy consumption is not there in machining and assembly. For your clear understanding of these four processes, machining, forging, sand casting and assembly.



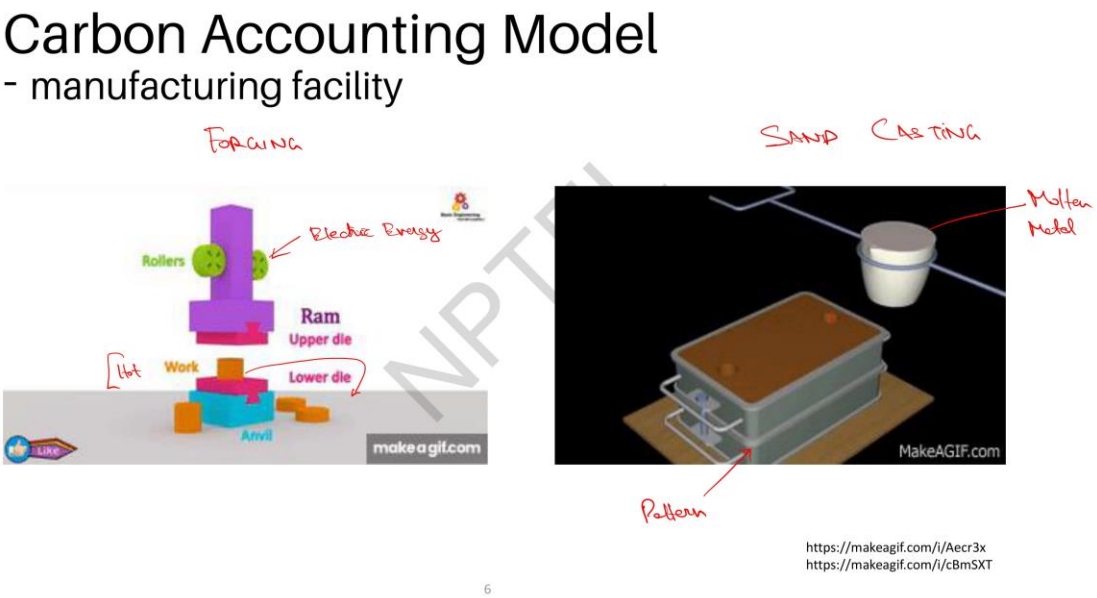
I would like to show you these small animations which are taken from these references. This is majorly a machining process. Here you can see this is a machine, this is a lathe machine in which boring is happening. Internally this is a tool, a tool that is entering the pipe here and it is trying to increase the diameter. This is my workpiece. This is typically a machining where the scrap would come out, the machine is rotating, there would be energy to rotate this motor, energy to take this carriage forward.

So, all those components would be there. This is machining. And this is assembly. You can see a car assembly is going on. Car wheels are being assembled here using a robot.

This is a pick and place robot. And this is our turn plate. Turn plate. So, there will be certain setups of equipment in assembly process. As you saw here in assembly, energy electrical consumption is there.

Raw material is not at all consumed here. In the machining process, raw material consumed. In assembly, non-electric consumption is not there. Waste disposal is not there. Direct carbon emissions are not there.

So, in the assembly that carbon emissions are not there. In the machining also that carbon emissions are not there.



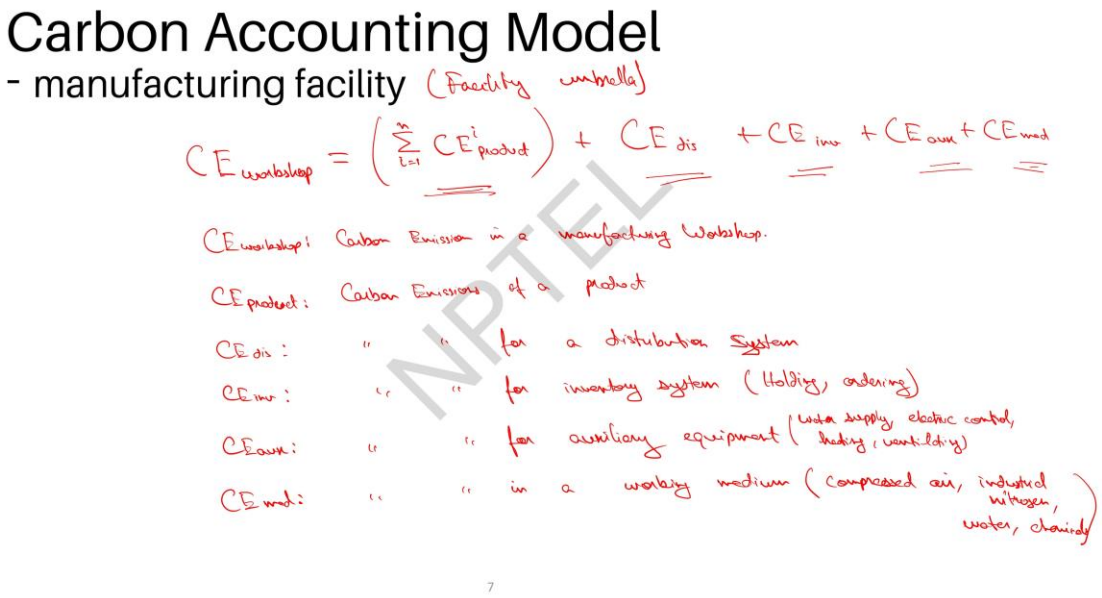
But that carbon emissions are there when we talk about a forging process. What is forging? We are just turning or converting the shape of a material.

For example, this is the shape, this is the height, this is raw material whose shape is being converted to this, the smaller size. So, we have rollers which are operated by electric energy. So, there is also heating. So, that is non-electric energy is also there. This is hot workpiece.

It could be hot forging, it could be cold forging. Both the processes are there, hot processes, cold processes. But typically, this is a forging process where we could see that the raw material is there and that is being converted to a different shape. Similarly, we have casting. Typically, this is sand casting.

In the sand casting process, this is molten metal that is being poured into a pattern that is made out of sand. And this pattern helps you to convert this material goes in and this material then converts into the component that is required. So, this is a component that is made here. So, this is a component that is ready that comes out of the pattern after cooling and this component is not very well finished. But here also because heating is there, fumes are there.

So direct carbon emissions are there here also heating is there in the forging the fumes are there that carbon emissions are also there and non-electric energy consumption is also there.

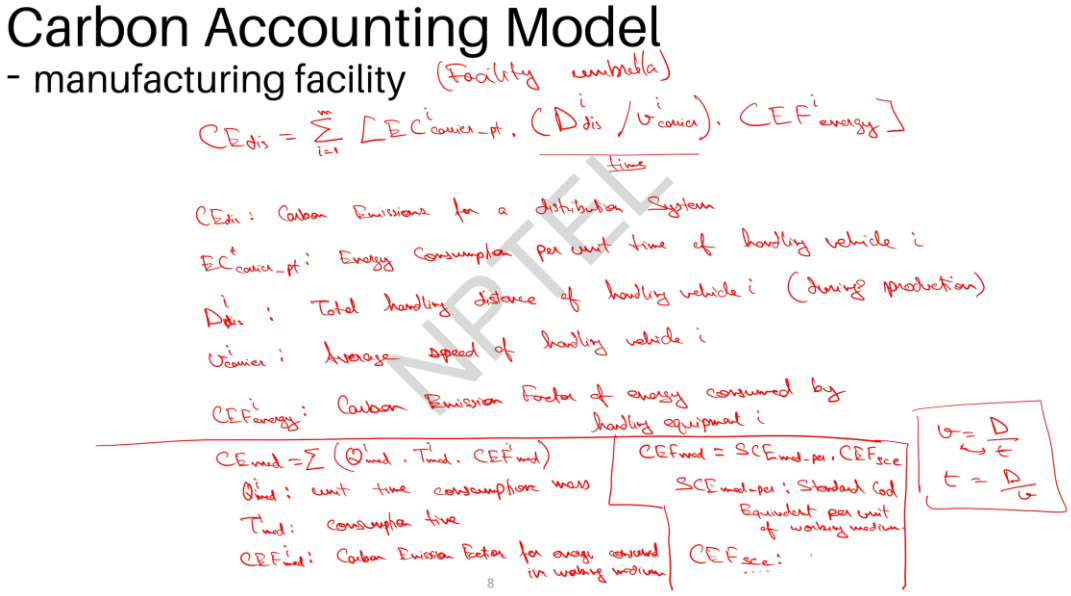


Let me now try to move to my workshop or facility model. So, if I try to talk about the carbon emissions in my workshop. I will try to notate CE as my Carbon Emissions. So, carbon emission for a complete workshop or complete facility would be the carbon emissions for the product.

$$CE_{workshop} = \left(\sum_{i=1}^{n} CE^{i}_{product}\right) + CE_{dis} + CE_{inv} + CE_{aux} + CE_{med} \quad (50)$$

That is carbon emission for product for I. So, this is in my facility. And after that, I have CE distribution carbon emissions inventory, carbon emissions auxiliary and carbon emissions working medium. So, to put the parameters here, so we have CE workshop is our carbon emissions in a product manufacturing workshop. Carbon emissions in a manufacturing workshop where CE product is my carbon emissions of a product and the others such as CE_{dis} is my carbon emission for a distribution system. Similarly, carbon emission for inventory. See inventory is my carbon emission for inventory. I will putting system because there would be carbon emissions for inventory holding for the orders which are being put.

It is ordering this is carbon emission for inventory and CE, this is carbon emission auxiliary are all my auxiliary equipment and CE medium is my carbon emissions in a working medium. Let us try to see these parameters, product, distribution, inventory, auxiliary and medium in little detail now. Regarding the product, I will try to talk about this in a complete detail and we will try to move into the development of the product. We will try to see the parts, we will try to see different variables in development of a parts even.



Let me first try to focus upon distribution, inventory, auxiliary and medium. So, what is carbon emission for distribution? Carbon emission for distribution is sum of the carbon emission that is EC for carrier. PT, which is energy consumption per unit volume of handling a vehicle I is there.

So, PT is per unit here. And this is a carrier that is vehicle. For example, if you are using a truck or we are using a loader to take the components from factory to the wholesaler. So, this is per unit time of handling vehicle I. So, I am putting I here as well. This is energy consumption. EC is energy consumption.

So, CE you know is carbon emissions for a distribution system. And Ec for a carrier per unit of time is my energy consumption per unit time of handling vehicle I. So, I am putting EC I here. So, this is I. This is energy consumption.

$$CE_{dis} = \sum_{i=1}^{m} \left[EC^{i}_{carrier\_pt} \cdot \left(D^{i}_{dis} / v^{i}_{carrier} \right) \cdot CEF^{i}_{energy} \right] \quad (51)$$

Total handling distance of handling vehicle I, this is during production. I am talking about a production system and distribution is taking from a production system. So, this is distance per unit v, v is my velocity or you call it the speed.

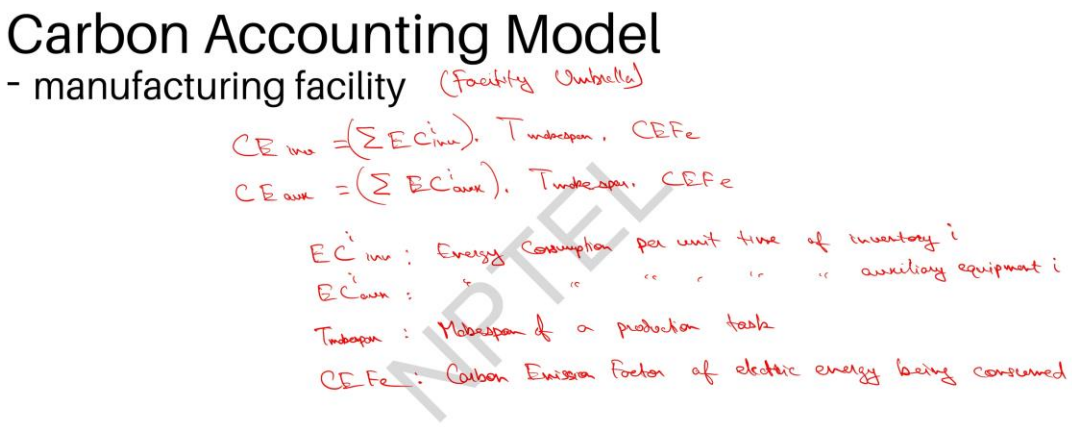
I will put it here average speed of handling vehicle. So, typically, you know, velocity is equal to distance upon time. Here, distance by v, what is it giving? So, I am interchanging these, this becomes time is equal to distance per unit speed or velocity. This I am using here to present time for which this energy is being consumed for the carrier.

So, this is energy consumption into the time, into the carbon emission factor, Cef, I will keep on using Cef throughout this lecture. So, this Cef of energy I is carbon emission factor of energy consumed by handling equipment, handling equipment I. So, energy consumed for my truck 1 into the time for which this truck 1 travels, time is distance per unit speed. This times the carbon emission factor for different vehicles could be different. If I am having a smaller vehicle, the carbon emission factor would be higher.

If I am having a larger vehicle, carbon emission factor would be lower. So, the carbon emission factors would be different. If I am having a smaller vehicle running on a gasoline or a petrol, the carbon emission factor would be lower in comparison to a vehicle running on diesel fuel where it would be higher. Similarly, for the number of components, if we talk about economies of scale, the equipment or the system or the vehicle that is of a larger size would have carbon emission factor lesser. And for the smaller size system or a vehicle, because it is having or carrying less number of components, carbon emission factor would be higher.

So, this is my carbon emission for a distribution system. What were the other systems I talked about here? The carbon emission for inventory. When we talk about inventory, we will talk about the make span. That is, we will talk about energy consumption.

We will talk about the carbon emission factor for inventory. We also talk about the T make span. Let me try to put that relation here.



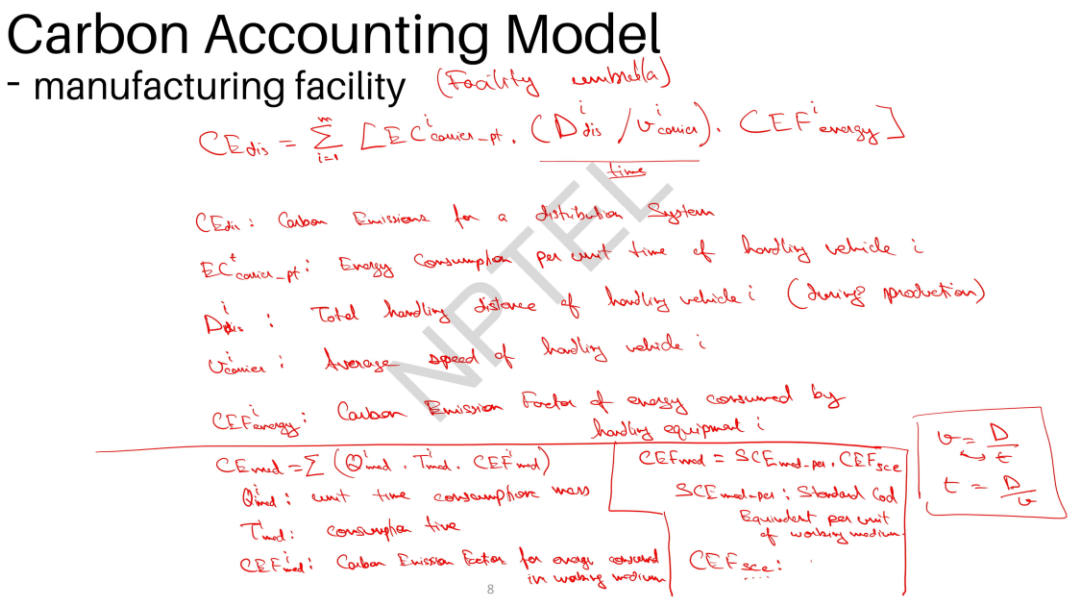
$$CE_{inv} = \left(\sum EC^i_{inv}\right) \cdot T_{makespan} \cdot CEF_e \quad (52)$$

$$CE_{aux} = \left(\sum EC^i_{aux}\right) \cdot T_{makespan} \cdot CEF_e \quad (53)$$

And here it is energy consumptions per unit time of the use of the auxiliary equipment. And I will put I here and this is inventory I, this is auxiliary equipment I. But this T make span here, different components have different make spans. Accordingly, different parts have also different make span. Make span means the time it takes for that operation.

For example, if it is just drilling a small hole, a hole of 10 millimeters of diameter into a sheet of 2 millimeter thick, it will take a few seconds. That is one operation. Similarly, if you have to do multiple operations like this, this make span would be smaller. On the other hand, if it is a complete machining of maybe carburetor of a car vehicle, it will take longer time. It is something that will take a few hours.

So, this T make span is for a specific task. So, this is make span of a production task and CEF as I mentioned, this is carbon emission factor of electric energy being consumed. So, we have discussed inventory, auxiliary, carbonation, we discussed distribution.



Now, what are we left with? The carrier medium. Carrier medium carbon emission, that also I will put it here itself.

$$CE_{med} = \sum \left(Q^{i}_{med} \cdot T^{i}_{med} \cdot CEF^{i}_{med}\right) \tag{54}$$

Carbon emission factor for medium is calculated as the SCE that is Standard Coal Equivalent for medium PER, this times the carbon emission factor for the standard coal equivalent.

So, here SCE medium and per unit energy consumed for working medium is my standard coal equivalent. This is standard coal equivalent of production energy consumption per unit of energy consuming working medium. Per unit of the energy consumed in working medium and carbon emission factor for the standard coal emission. So, this gives me my carbon emissions in medium. So, here now we have completed this task and we have taken or dotted down the carbon emission for distribution, inventory, auxiliary and medium.

Regarding the medium, there are certain mediums which are there in a manufacturing concern. It could be a compressed air system or so. Or it could be industrial nitrogen for cryogenic treatments or it could be water or any chemicals or so which are used in industry. So carbon emission in a manufacturing facility or workshop include these

systems and we are talking about the distribution system inventory system auxiliary system and the medium auxiliary system. Includes not even lighting and ventilation it also includes water supply it also includes electrical control.

I'll put it here water supply system, then electric control systems, heating and alternating, definitely I have put. Now, let us take a break here and then I will continue the next part of this lecture. Where I will talk about in detail the carbon emission for a product. In carbon emission for a product, we will see the carbon emission for parts, carbon emission for transfer. In the part itself, we will see further details for each and every operation in machining.

Then we will also try to see forecasting for the forging. And we will try to then move to the single unit process and from there itself. How the model is being built to a overall factory or a facility or workshop design and carbon emissions are captured there. And these all but I am talking about are the graphic user interface backend. Backend means when a software is designed the backend in the software there are certain algorithms written and certain programs are written and those are all calculated.

These are the programming languages that I discussed about in the last week. And the next week, Dr. Prabal Pratap Singh will be discussing the details of the laying down the program to develop your own model, to develop your own interface and the software, a small program we will discuss. So that you not only depend upon the existing software which are paid, you can develop your own model. Carbon accounting system for your own product and that will help you to understand or take your product into a greener function better.

Thank you.