Carbon Accounting and Sustainable Designs in Product Lifecycle Management

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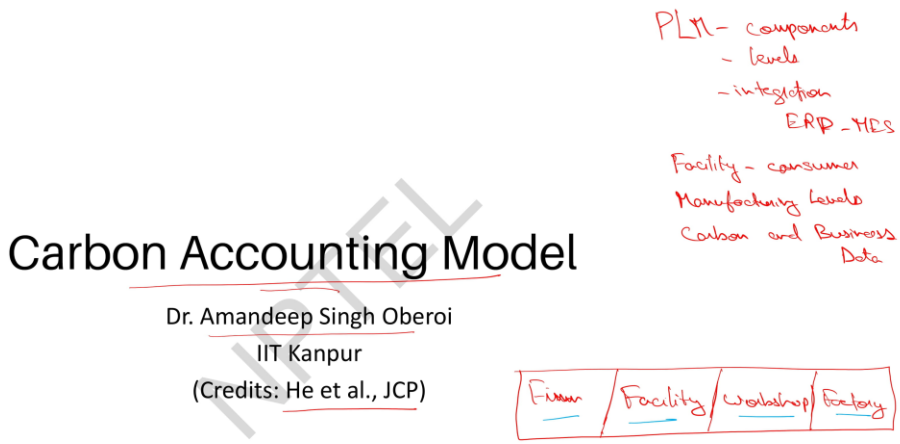
Week 08

Lecture 34

Carbon Accounting Model (Part-1)

Welcome to the week 8 of the course Carbon Accounting and Sustainable Designs in Product Lifecycle Management. In the last 7 weeks, we have discussed the concept of the Product Lifecycle Management and connected Carbon Accounting to it.



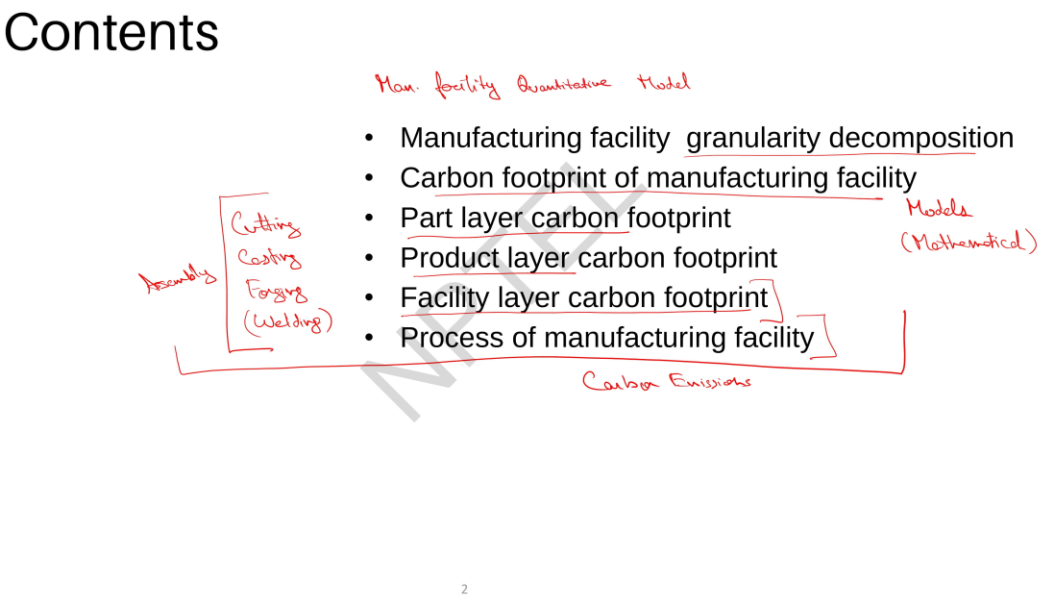
I have discussed regarding the PLM, its components, its levels, its integration with ERP and MES. And then we talked about facility and consumer, where does consumer stand.

When we talk about facility design, that is facility consumer connection we talked about and we talked about levels of manufacturing within facility, out of the facility manufacturing levels. And in the last week, I talked about connecting the carbon and business data. And there we had different layers. There was a functional layer in which product design, process design was there and manufacturing, education system had been there in the system layer. How do these layers connect with the carbon layer to capture the data?

Now, this capturing of data we will learn in this week. In this week, I will try to give you certain models where we will work within facility. I will keep on using the words, facility, workshop, factory or a firm, manufacturing firm interchangeably. Which means we are talking about a facility, where tangible products are developed. Because, we are talking about product lifecycle management.

I will give you introduction to service lifecycle management to applications lifecycle management. Like you develop applications for windows, for ios, for android. You develop systems for services, so those also will discuss in the end of this week or in the coming week. But right now, we are talking about the product. When we're talking about the product.

Product has to be manufactured, we talked about the cradle to grave flow of the product. And we are now talking about within facility, means when the product is under development. It is from the design to the manufacturing, after manufacturing, it goes to the user that also flow. We have season now within facility, how do we capture? The carbon footprint, this we will discuss in this week and I will talk about manufacturing facility and its granularity decomposition.



And this is the same decomposition that we discussed in the last weeks. That is product design was there and product design different functions were there. Different functions had different parts, then we try to talk about the process design. And whatever is there in the product and process design and facility that would be more detailed. Other concepts like order management the equipment monitoring systems the SCADA those part would be little out of the scope of this lecture.

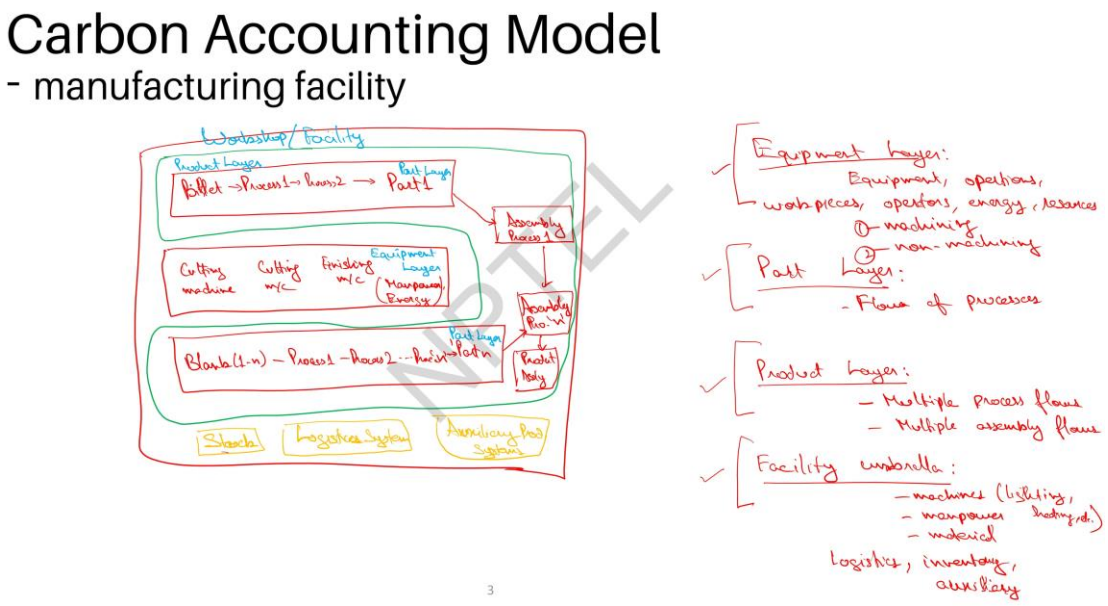
Regarding the carbon footprint of a manufacturing facility, we will try to see some models. When I say models, we will try to talk about mathematical models. So, there will be lot of relationships, lot of equations in this lecture. And you might have to go through some broad equations like for example, carbon footprint total for the facility is the sum of carbon footprint direct and indirect. Indirect could be further divided for the material for the energy and for the waste disposal or waste treatment.

So those small equations you will see and also some detail. I will go into the equations that the mathematical models. When I talk about the part layer and product layer in the part layer or the product layer. I'll talk about different processes that is, I will talk about the Cutting processes that is machining. I will talk about other than cutting.

I will talk about casting and forging and some quick introduction to welding as well. Like any product that is to be manufactured or any component that is to be fabricated using the

cutting process. Cutting process is removal of the scrap from the material and to come up with a shape whatever is desired. So those we will discuss through this lecture and then we will talk about the facility layer carbon footprint. This I will cover first, facility layer footprint and process of manufacturing facility we will again discuss.

Try to cast a quick glance upon that we discussed in the previous weeks as well. The manufacturing facility quantitative model is the major part, I will cover here. And when I will try to talk about the facility, I will also try to talk about for assembly. Wherever the components are fabricated finally these are to be assembled to be a single final product. We will talk about this in the context of material, energy and waste disposal. And we will see how do we have the carbon emissions connected to all of these.



So let me start with my layers that I mentioned in the content slide. We have equipment layer. Then we have part layer. Then we have product layer and complete we have a facility.

You call it a facility or call it a facility layer or umbrella. So, we have a manufacturing workshop. So, I am talking about part layer. If you say I am only talking about say a part one, right. This part one let it be some part that comes from the very raw material.

I will say, I have a billet here, right, from the billet there are certain processes. The process layer, if you call the process one, then we have process two. And after two process this converts into a part and this part then goes to an assembly. I will call it assembly process 1. This enters here.

That is part 1. Then for all these processes to work on a billet, B I double L E T, process 1, process 2, we have equipment in parallel. I would have on a billet a cutting equipment. I will put a cutting machine. Then I have processes 1 and 2 which could be cutting, which could be maybe finishing.

Or anything that is maybe known cutting just to polish, just to paint or so. These are all again machines or systems here. This is another layer. So this is part one I am talking about. There will be multiple parts like those such as this is part one.

I could have another part which is made from a blank. Blank is a sheet. Blank may be, I would say blank 1 to n. Any number of blanks are there in which process 1, process 2, so on till process n makes it to the part N. This is part N that is procured here or made here.

This is again a part layer. Now, here I have layers and this is an assembly again. Assembly process N. There could be assembly equipment as well. So, what I am trying to put here is different layers in manufacturing.

Which I will discuss through the course of this lecture, In which we have a product layer. I will put a product layer here. This I am talking about a product. Equipment layer would be different from product that is here. This is equipment layer and there would be operators there would be a manpower.

I'll just again put it here there would be manpower energy or other resources that we have discussed in the previous weeks. So again down here, we have another layer these two are part layers. So, what is my product layer? Other than the equipment, whatever parts I am trying to develop, those are the product layer. I will put it in a green envelope here.

So, this all is my product layer. I am just keeping out the equipment layer out of it. And complete block that I have drawn is our manufacturing. This is my workshop or facility. It could be, as I said, the facility, workshop, factory, firm, whatever you wish to call it.

And here also we have, the stock of raw materials, stock of manpower. We have logistics system or we have some auxiliary production systems. Auxiliary systems, I am talking about auxiliary production systems. These all would be also part of the workshop that

support your equipment and processes to develop the parts and parts assemble to make a final product. So, here I will put one final assembly that is my product assembly, it would be here.

So, what essentially now is equipment layer? Equipment layer is the operation of equipment, operators, work pieces. And you need operators for them to work on the operations and other energy and resources. So, we can divide a manufacturing facility into machining and non-machining processes. Machining processes mainly include tit-turning, milling, drilling.

I will show you a video in the laboratory environment that how the energy consumption or energy flow goes when we talk about a machining setup. For non-machining, it could be anything such as stamping, casting, forging, assembly, anything where cutting is not happening is non-machining. So, it could be, I will put it in two ways, machining and non-machining. This is one and this is two. This is equipment layer.

Part layer, as you have seen, we are trying to develop a part through the basic raw material that is billet entered in part one, blank entered in part N. And we are trying to develop a part which goes through certain process flows. And the part is processed, it could be a machining process, it could be a non-machining process, but specifically for that part, these processes are there. So, this is part layer. So, where I would put a little detail, it is flow of processes, then comes product layer.

Product layer includes all the different parts and assembly. Whatever you could see in the green envelope is my product layer. Where collection of all the products output by the assembly and the corresponding assembly flow in the facility is there. The assembly processes for each and every product can include multiple assembly flows, multiple process flows. And it only has one target to come up with the final product here.

It has multiple process flows or multiple assembly flows. Then this all is happening within a facility or workshop. Which contains all the resources which are being incurred in development of this product. These resources could be material, energy. If you wish to talk about the manpower, the man hours which are there.

So that also could be taken into consideration. So facility layer is the overall layer that we discussed about where we have the major output resources, machines, manpower. So, it is man, material, money. Material or anything related to them. For example, if you talk about material.

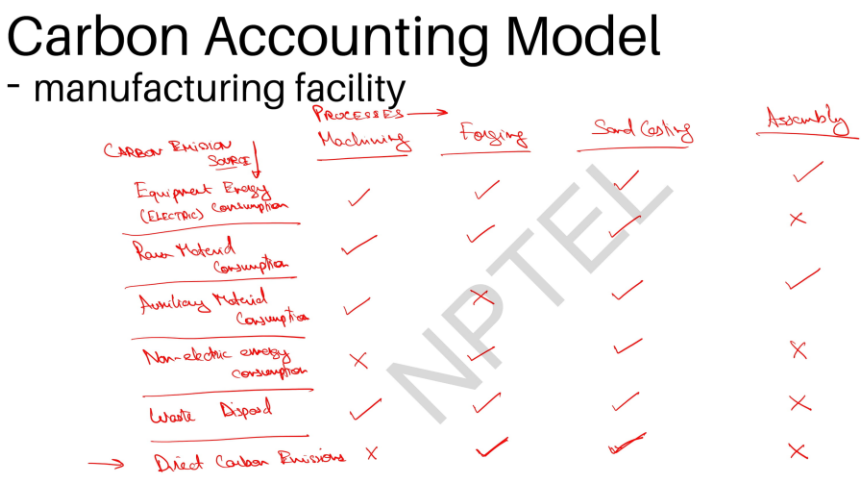
There would be inventory system that is holding the material or stock that I have put here or there would be logistic systems, logistics, inventory. I would put here auxiliary. Auxiliary means your systems which do not correspond to the direct carbon emission, but it is there in the facility. For example, it could be heating, ventilation, air conditioning system. There could be lighting.

There could be the office systems also, stationary. All those parts come in the auxiliary systems here. Now, also in the equipment itself, machines also have multiple inputs in it. For example, the lighting in the machine, again, the ventilation, heating, water supply, whatever other things are there. The ventilation, heating, water supply and so on, I will just put etc.

So, this is how the layers are there. I will start from the facility umbrella for the overall facility how do we calculate the carbon emissions. And what are the certain quantitative models or mathematical models for it and then I will move to the part layer. Part layers from parts to we will try to understand certain processes. And we will then try to move to the product and try to understand the overall carbon emission model for a manufacturing facility.

Again, I would stress, I am talking about a manufacturing facility. In a manufacturing facility, what is happening that we will talk about. It is material when it enters the manufacturing facility, we will take as one of the variables. Material just goes out of the manufacturing facility, that is the distribution. That also will take one of the variables, but majorly what happens within the facility, that we will take in detail in this lecture.

Now, Let me try to first understand the carbon footprint of a manufacturing equipment layer for four typical processes that we will keep discussing throughout the lecture.



So four typical processes that we will discuss would be machining. Then I have forging, sand casting, and assembly carbon footprint input or carbon footprint emissions of the manufacturing equipment layer of these four typical processes. We will try to understand that what are the process types and what are the consumption patterns. Here for instance if i have equipment energy.

This is one of the parameters that we will discuss. We will discuss about the raw material consumption. We will talk about the auxiliary material consumption. And when we are talking about equipment energy, we are talking about consumption of electric energy. So when we are talking about energy consumption in equipment.

Here we are majorly focusing upon the electric energy. Other than electric, there will be non-electric energy consumptions as well. We'll discuss on them. And these are all the inputs, majorly raw material, auxiliary material, non-electric energy or electric energy in the terms of maybe machining is majorly electric. All of them would be using electric energy, whatever processes we are talking about.

There would be waste disposer. And direct carbon emissions some of the processes also give. Here, regarding equipment energy consumption. So all the processes would consume electric energy. That is, it is there in machining, it is there in forging, it is there in sand casting, it would be there in assembly.

Like even if you are using a drill machine or if you are using a hand rotor to screw or unscrew a nut or a bolt. So that is also consuming electric energy. That is, in the assembly itself as well, the electric energy or equipment energy would be there. Then raw material consumption in machining, there will be raw material, there will be scrap coming out. In forging also, raw material will be consumed.

In sand casting as well, the raw material will be there. Assembly would not use raw material, only it will assemble whatever raw material is being supplied to it. So, this parameter for raw material consumption would be absent when we will talk about the assembly processes, carbon emissions. Auxiliary material consumption, auxiliary material that is the tools, the cutting fluid etc. So those would be there in machining, those would be there in sand casting, those would be there in assembly.

In sand casting, what are the auxiliary materials? We will have different components of the sand casting system. There are fillets, there are sprue or so. Those are all auxiliary materials. In assembly, there will be certain system.

For example, for taping, there will be tape rolls. There will be painting systems also. Those will all be there in assembly. In forging, we do not have any auxiliary materials. Material consumption because forging is a process where material only changes its shape.

That is, one shape is converted to another shape while pressing, while stretching or any other processes like those. Then comes non-electric energy consumption. In machining, majorly or almost all the energy consumption is from electric itself. Therefore, the non-electric consumption would be nil here and also in assembly, the non-electric consumption would be nil. What is non-electric consumption?

We will talk about when we will talk about forging and sand casting, which has non-electric consumption as well. Waste disposal is also there in machining. Scrap is there in forging. Some waste disposal is there in casting. Waste disposal is there in assembly.

I will discard the waste disposal input. Because we are considering that whatever is coming in is going out. And we are not talking about the quality control systems here. Where maybe one out of a million component is not within the conformance limit and that is taken away. We are just taking in this model whatever is coming as an input as parts to the assembly system is assembled and that makes a product.

So therefore the waste disposal here is nil. Then, direct carbon emissions. So, when we are talking about the non-electric energy consumption. There would be direct carbon

emissions in forging and sand casting. That is, fumes would be there because we are melting a metal or we are heating a metal.

There would be air pollution. There would be water for treatment of the forged or casted components. So, direct carbon emissions are also there which are not there, predominantly in machining and assembly. I think this table would make you understand what variables are present in what kind of the processes. These are processes and here I have carbon emission source.

So, with this I have developed a framework, where we will try to now understand a quantitative model. And we will try to understand the relationships that is the mathematical relationships in these carbon emission sources. And the processes that machining, forging, sand casting, assembly. Majorly I would be talking about the machining process. And what I am discussing in this carbon accounting model is taken from this different research publications that you keep asking in the forum, what is the source?

So multiple research publications were referred. Majorly you can visit here at all in the journal of cleaner production and you will find the maximum model that I am discussing in this week. And I am closing this part of the lecture. In the next part, we will start discussing the mathematical models.