Carbon Accounting and Sustainable Designs in Product Lifecycle Management

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Week 06

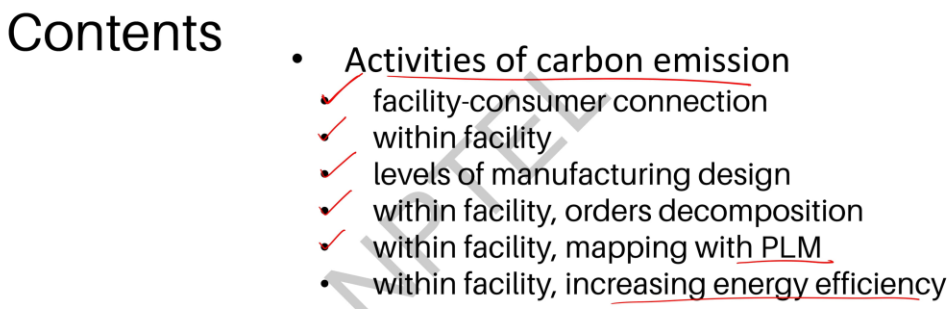
Lecture 26

Facility Carbon Accounting

Welcome to the next lecture in the course Carbon Accounting and Sustainable Designs in Product Lifecycle Management. We had discussed the Product Lifecycle Management in detail in the last few lectures. We have discussed about the components of the product life. We have discussed about the components of the complete PLM process. We saw how PLM is related to the MES (Manufacturing Aggregation System).

How is related to the Enterprise Resource Planning? Let us now see certain other aspects in the carbon accounting of a complete facility. So, I have titled this lecture as facility carbon accounting.

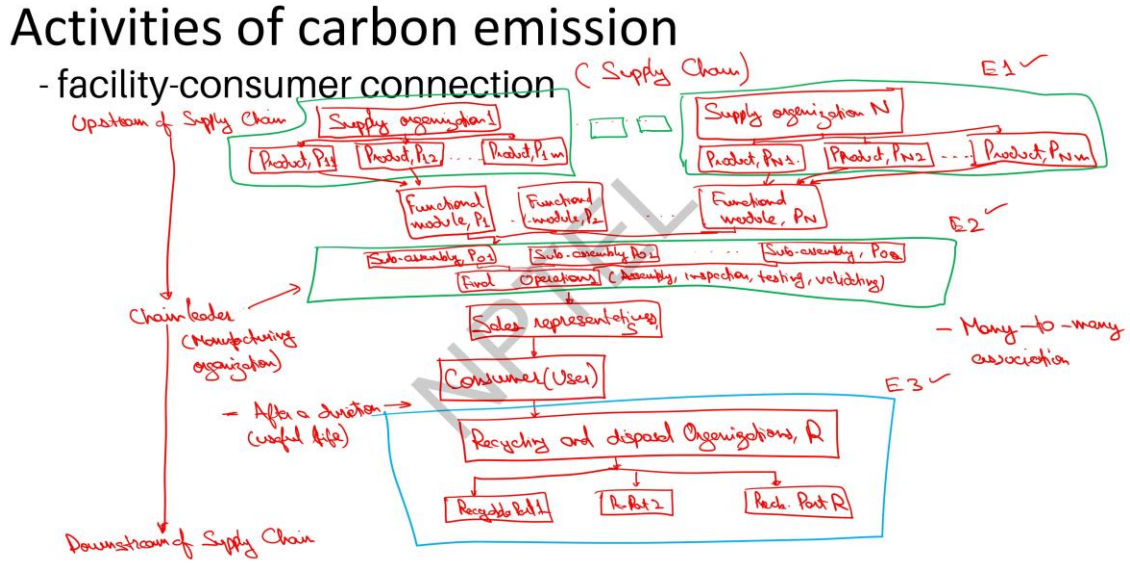
We will try to understand some activities of formation and we will try to understand certain models that how do we connect activities. How do we break the activities from a overall facility to the production lines to the unit level and try to understand the direct and indirect carbon credits or carbon accounting into them.



Now, certain pointers that we discussed in the previous lectures, I would like to now discuss in relation to them. Activities of carbon emission facility consumer connection, we will say like how is the overall product life that is when the consumer is using the product. I have talked about during use and before that it is before use after that it is after use. So, all the pointers we will try to have a connection then within facility that is before use when the facility is manufacturing something majorly. This manufacturing facility what are the connections within them.

Then we will also try to see the levels of manufacturing design. In manufacturing design we will try to see different levels and different decisions that we need to take. And when we try to connect these decisions from the very broad maybe supply chain management to the very small decision on picking a specific tool for specific machining also.

Then within facility we will see how does the vendor development, how does the orders decomposition happen? Then mapping of these facility entities with the PLM system we will try to see. Then certain strategies to increase the energy efficiency would be shed some light on.



Let us now try to first see the facility-consumer connection. When I try to talk about facility and consumer, I am talking to talk about something that in the supply chain when a user is here this is my user or consumer right or I call it as user. So, this user is receiving products from a facility and user only connects to a sales representative. We are talking about the product supply chain that encompasses many node organizations including the supply center, production facility, sales organizations.

The end users that is my consumer and further recycling and disposal facility and further distribution facilities. Let us try to see all of them. We are having a sales representative here or sales organization that is connected to the user. For where does the whole story start from? It comes from an organization that is my manufacturing organization or I would because I am talking about here the supply chain.

And I will try to talk about the flow of supply chain from the upstream of supply chain, to the downstream of supply chain. There is a flow in between there is a connection, I will call it as chain leader. I will come to the point what are these specific nodes that I am going to discuss in this slide. So, this manufacturing organization you call it a supplier

organization. I will call it as my supply organization 1 and there are certain supply organizations 1, 2 and so on.

And I will call it till the supply organization N. So, this supply organization has its multiple products or goods that it is developing. I will call it as the product of supply organization that is product P first organization first product then they could be product P first organization second product. So, on up to product P first organization and I will call it as mth product 1 m. This supply organization is supplying while developing these products will try to make a connection with if you can see I am also making arrows.

So, we similarly let me say this supply organization N is also producing certain products. I will call it product PN1 then it has product PN2 so on up to product PNM these products are being developed here from this organization. This becomes my supplier entity. It itself becomes my supplier. Different, for example, in car manufacturing, we have been quoting the certain examples for Toyota manufacturing or so.

In the Toyota manufacturing system, I will also show you some video in the end of this week that how Toyota is taking certain initiatives to reduce its carbon footprint completely to zero by 2050. Let me say the car manufacturers are trying to now having one set of suppliers who are trying to supply only the components being used in the interiors of the car. Maybe the seat covers, maybe the seat cushions, maybe the dashboard small parts of that. So, who are the people who are supplying these? This is one set.

Second set is where is the engine procured from? Then along with the engine, small other units that which are connected the walls. The other pointers which are there, those are all connected from another organization. So, I will put these organizations into separate sets here. This is my set 1.

This is my set N. In between, I have multiple sets of the suppliers who are trying to supply their components, their assemblies to our system. And we have our own manufacturing organization here where we try to have functional products here. I would say functional products module of my organization this is functional module for the product P1. It is P1 means product all the products from supplier 1 may be all the polymer products all the products plastic products.

So, they could be simply other functional components from P1 2 Pn. I would say functional module P2 so on up to functional module Pn here is my capital N. Now, these take the products from these organizations. So, maybe this product one that I am talking

is taking the product inputs from these existing products or may be an nth product is giving inputs here and so on this is how it goes. Now, comes here my manufacturing cell.

This is my manufacturing cell where I have my products being taken from these different functional modules. I am talking about functional modules only because the products or the components or the assemblies or the parts which are taken from the supplier organizations are not the complete product. When I use a word product simply product means the final product that is reaching the consumer. I am using the words products, components, assembly interchangeably. But here, unless I have reached the consumer, I am talking about only the parts or the assemblies or the sub-assemblies of my complete product.

Now from the supplier organization 1, let us work into leather or maybe the fibers. So the roll of the fiber that is taken from the supplier organization 1 that is used to stitch the seat covers which are used in my car. So, that is one function. So, the function here is stitching, designing the seat, cover, profile that is function. Now, supply organization and could be only the engine components.

Engine components it is could be the set of the organization, set of the companies which are supplying us the components. That is the raw material for the engine, the different tools for them and so all these things come from those functions. Now, these functions now help us to develop the final subassemblies which goes into my final product. So, I would say the functional module helps me to develop a, I am calling it subassembly, subassembly P1. I would say O1 that is operation 1.

Then I have sub assembly PO2 and so on up to sub assembly PO, I am putting here POQ here. Because number of functions could not always be equal to number of the sub-assemblies that we are creating. So, these small sub-assemblies are being created here. So, after the certain operations here, I would only call it as operation or I will call it as final operations. Final operations could be the final assembly of the sub-assemblies putting all the parts together then final inspection and everything it could be.

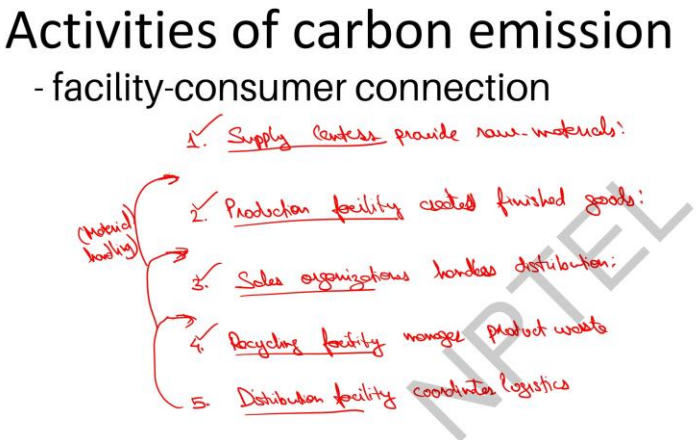
I will put it in bracket assembly then inspection testing, right validating and so on. These are final operations. So, these are there which makes our product ready. So, these sub assemblies now taken as input to my final assembly. Now, this sub assembly system could take input from any of the functional modules here, right.

I am putting all of the functional modules is giving input to my envelope So, this is my I will call it envelope 1, this is my envelope 2, right. Now, this product then goes to the sales representative, sales organizations. I will represent 80s, I will put S here as a plural word. So, S that takes the product to consumer.

So, now I have talked about something before use what are the connections. Let me also try to jot down the list of the different organizational functionals here. So, let me now talk about or jot down the different activities when I am talking from the upstream to downstream of the supply chain or the supply chain the certain components which I am talking. Let me try to put it in a separate slide here. First point in facility consumer connection is supply centers provide raw materials.

Then production facilities create finished goods. Then there comes the turn of the sales organizations. Who handles the distribution of the product? I am till this point. Well, the sales organizations or sales representatives have handed over the product to the consumer while it is obviously the sales that matters finally.

Finally downstream the supply chain we are talking about the complete supply chain, here we have recycling and disposal organizations. So, this organization I will call it at R. This is the part that is after use. So, after use recycling and disposal comes into the play where recyclable parts are now taken to the different areas wherever they could be finally disposed of. It could be I would say R recyclable part. One recyclable part two and so on up to recyclable part R. So, I will put a different envelope color here. This is a blue color that is after use.



Now, let me also put these pointers here. That is next function that is taken is by the recycling facility. I would put here recycling facility manages product waste.

Finally, there is also one facility that could come at anywhere in these I will call that as our distribution facility. Distribution organization or distribution facility coordinates logistics. So, this could come at any point. Now, there are certain nodes which I have given here supply centers, production facility, sales organization, recycling facility, distribution facility. If you try to again look at the illustration that we have given here.

So, this is envelope 1, envelope 2 and we have envelope 3 that is post usage. Now, product life cycle encompass many stages that align with distinct nodes within the supply chain when we try to move from upstream to the downstream. So, there is an examination of many to many associations that is multi-faceted association. Now, these are between the individual organizations and a product can be undertaken within the context of the product supply chain. Now, manufacturing organization assumes the role of supply chain leader here.

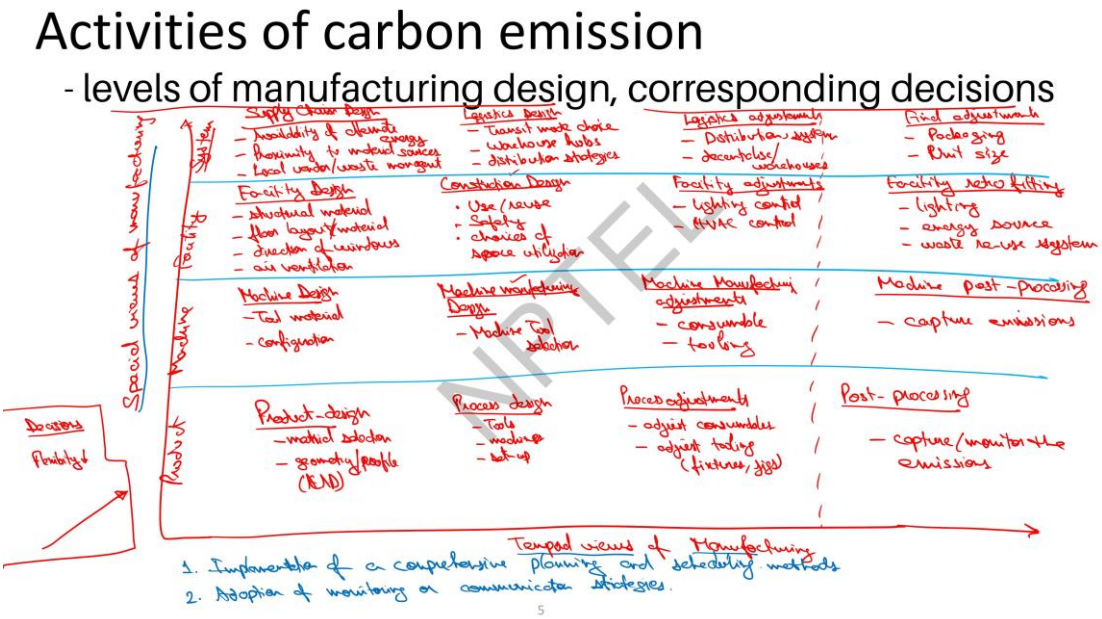
So, chain leader is our manufacturing organization, where the goods that originate from the supply organization. That is raw materials and components are taken from the supply organization and these undergo the processing and assembly within the manufacturing organization that is why it is called as chain leader. The completed products are then conveyed or transferred to the sale organization for the purpose of the sales or selling it or delivering it to the end consumer. So, upon reaching a specific duration of utilization, so this is after a duration. I would like to just mention it here.

After a duration, what is this duration? This duration is the useful life of a product. After useful life, it goes to the recycling system. Now, supply chain centers provide raw materials that is essential materials for manufacturing, forming, the foundation of product and assembly. This is their production facility creates finished goods that transforms the raw materials into ready or market ready products through assembly and quality control processes.

Sales organizations handles distribution that is the role they play is marketing or it manages marketing. It manages sales, it manages distribution to deliver the products to the end user effectively. Recycling facility manages product waste that is recycling of end of life products or they try to reduce the environmental impact in total. Distribution

facility manages, coordinates the overall storage and transportation to ensure the timely delivery at any point whether to sales organizations, whether within the facility. Actually, distribution facility major is concerned with the sales organization only when we talk about distribution.

Within the organization, it is material handling. So, I will put it here. Here, material handling is also there. These are different activities of carbon emission.



Let me now try to see the levels of manufacturing design when I am trying to talk about the supply chain from upstream to downstream.

Now let me try to take it from the downstream to upstream because we discussed that the product carbon accounting when we try to see divide the overall organization into different departments. In those departments different functions are there. Those functions could have different operation lines or service lines. We also call it those as production lines. Those production lines have different workstations.

In those workstations, the specific one operation that is called as a unit work or unit cell. In that unit work or unit process, we will try to see what are decisions. So, corresponding decisions and levels of the supply chain that is try to see here. First of all, I will try to say there are major four temporal levels. When I say temporal levels like with the time those change.

With temporal level if I say there is something known as product design. After the product design that is the initial stage of the design or production process. During this stage there is a greatest potential to have an influence on the environmental effect as we discussed in the PLM overall process as well the design has to be in such a way the sustainable design. So, that the overall life of the product is enhanced overall carbon consumption is enhanced. So, this is product design with the major decisions are taken after the product design definitely as we discussed in the previous lectures comes the process design.

Process design refers to creation of a production process that aligns with a fixed product design, a specific product design. The ability to optimize the system is restricted to establishing tools and techniques that are compatible within the defined design. So, here also there is a high degree of control of execution of the product in all aspects. So, it is finally permitted by the product design itself that what is going to happen in process design. So, after the process design, when I try to talk about the temporal level, we have process adjustments.

What I called as change management process. Process adjustments means fundamental production ah overall remains same. Minor modifications to the process may be made by selecting or optimizing process parameters that is may be to regulate important characteristics. Such as precision, such as amount of energy, amount of consumable required those all are to be optimized. So, that is process adjustments and definitely the change management process adjustment is happening when I am trying to talk about the temporal level.

This is I am trying to talk about the temporal views of manufacturing. In the temporal level, we have the post processing of the product. I will call it as post processing. See I am talking about the temporal view that is what specific in the product design we can pick the material that is to be taken. Then I can talk about the size or geometry or I would say the profile that is I am trying to talk about the computer aided design here.

Correspondingly in the process design, what processes would be there to develop the specific product that we have taken. If the material is only polymer, maybe we can go for 3D printing. It is also very inexpensive nowadays to go for the 3D printing or the additive manufacturing in the polymers. In the metals itself, if the drawing is very complex, so then also we can go for additive manufacturing. In the metal materials, if drawing is not

very complex and we also need a large number of components, we can go for CNC machining.

So, selection of tools. So, choice of tooling, then I would say machines, overall process that we will see, right. Then we will see the setup of machines. I will talk about these in detail. So, process adjustments are also there that means adjust the consumables or we adjust tooling.

As per our current product, it could be anything consumables, tooling, consumables are the materials, tooling is the specific machine or the maybe you might have to have some fixtures, right. Jigs designed for the specific product that you are trying to develop. Then post processing I will try to talk a little later. Let me first try to talk about product design, process design and process adjustments. And also I will try to talk these in the context of this spatial views of manufacturing.

So, from the spatial viewpoint, when I am trying to talk about the product design only, it was choice of the material, it was choice of the geometry. So, when I talk about spatial view, I am talking about the scope of the machine now. I was only talking about one specific process here in the process design material. Now, let me try to talk about a full machine where this design could be taken. That is the kind of a production line or equipment level design.

Then from the equipment level, the next special level could be the facility. What facility? The different production lines in the facility that could be taken from the facility. It could be taken to for that facility or the set of facilities that you have. What is the overall supply chain?

So, I will try to put here is this is product level. Then we have machine level. I will try to talk about machine level. Then I will try to talk about the facility level and finally. I will talk about the overall system level the production system or supply chain system whatever you call.

So, here let me try to draw lines here. So, that I differentiate between the product and machine level further it should be differentiated from the facility level and then the top. I have the system level or the supply chain level and also there are different connections of specific which are there. For example, if the choice of tooling is there specific tools are there then the machines which you select also are to be accordingly. If I say here I will put it as machine design.

So, let me talk about machine design here. In machine design, I will now try to pick the tool material. Which tool material would I pick or what configuration of machine would it be there or at a higher level from the product at a machine design level. Which was the process design here. I would have machine manufacturing design machine inflection design that is what specific choice of tool you would have I will call it as machine tool selection.

What machine tool you would like to do? If I go further in parallel to the process adjustments with a higher level of the spatial viewpoint I will try to talk about machine inflection adjustments. So, these adjustments are very similar we adjust consumables. We adjust the tools or fixtures as those were there in the process adjustments, but these are at the machine inflecting level now. Also similarly we have machine post processing.

That is we try to capture the emissions in the post processing of the machine. I will try to talk about see in post processing what is there we try to only capture or monitor the emissions. Similarly, we capture emissions here. The post-processing refers to the application of finishing and abatement techniques to regulate the precision of the part and to minimize the environmental impact. At this stage, there is no control over the process itself and it has already been created here.

The process is created in this level. So, in the post process it does not have any control here. Only we try to now capture emissions that whatever as happening post manufacturing, we try to minimize the environmental impact in that. So, different time periods and levels of organizations are there in this illustration. So, we provide insight to the intricate process of capturing and transferring information in manufacturing processes.

To make efficient decisions it is crucial to understand the necessary quality and quantity of information that should be exchanged between different levels which I am showing here. Additionally, one must grasp how decisions made at an early stage that is in the design stage itself can spread and impact different spatial or temporal levels. So, now let me try to see at the facility level I have my facility level design in which I will try to talk about the construction, I will try to talk about the structural material. Then flooring requirements case if it is a heavy machine we need to have a foundation for those heavy machines. We cannot have very smooth tiles where a heavy components are to be taken.

And for instance the trucks are to be brought for the material handling, the cranes are to be there, overhang cranes are to be there, the trolleys are to be taken. So, floor design is

very important. Floor layout and I will also put here material. In offices we can use anything matting or anything that we wish to put for the aesthetics viewpoint. In the facility design lighting and air ventilation is very important.

So, that is the direction with respect to sun that is also very important. I will try to say here direction of windows or doors etcetera then I will try to say the air ventilation. Because these heavily effect your use of the heating, venting, and air conditioning systems. So, that facility design is also very important here. Now, with the facility design, we also have the construction design.

Once the facility is designed like the productive design, then we go for the process. Once the facility is designed, we go for what construction would happen here. Construction design that is we try to pick the equipment, we try to pick the waste management system, we try to use reuse, we try to talk about safety, we try to talk about the choice of space utilization they could be time as one of the factors. Multiple things could be there.

Then facility adjustments. Certain adjustments if I say in the terms of facility it could be the lighting controls right. The HVAC controls, right. Who is to be given the control? Specific rooms, specific halls would be given or centrally it would be controlled.

So on. Post construction of the facility, There is no scope of the change of the overall structure. Post-processing, if I say like post-processing, like post-processing of the machine, it could be only retrofitting. Out of the full hall, we can create small cabins.

Out of a full manufacturing facility, we can create small cells or small process designs or product designs. For example, some is one product that is to be manufactured in very large number. We try to take a product design there, product layout there. That is specific set of machines are put in series. That product goes through all the machines and the multiple number of products are produced, right?

So, this is product design. Process design is specific set of the processes. For example, this is only 3D printing. This is only stitching of the sheet covers. This is only maybe drilling systems or so.

So, these all process designs would be there. So, these retrofit processes, systems or retrofitting of the systems could happen only once the facility is ready. I will put it as facility retrofitting, right? Here retrofitting again could be as we said about lighting, it is very first part that I will put here, right? Then source of energy whether all the energy is taken from the grid itself that is in India majorly thermal power plants are there for it or

you would like to have solar power rooms or would like to have some wind powered rooms.

So, then we try to design the retrofitting system in such a way that the waste reuse system is designed perfectly. Now comes the system level, when we talk about system level I am talking about the overall supply chain system. When we talk about supply chain system, the input to the facility from the supply chain is raw material. But when we design our supply chain system, there could be certain designs that overall have our carbon footprint as minimum as possible. Those could be designed accordingly.

So, those could be maybe we try to have a supply chain design. In such a way that we have the proximity to alternate energy availability of alternate energy sources or systems or we have proximity to different material sources. Definitely when we are talking about supply chain the localization or local waste management or local purchase would always be preferred. I would say local vendor or waste management when the supply chain design is there.

What is the executional part there? Like manufacturing aggregation system was here, product design is there, here product process design is execution, machine manufacturing design is my execution, construction design execution. Here execution is taken by the logistics, the different tools or different equipment or vehicle you use for supplying. So, we try to put here the logistics design. Let us we try to make different choices of the transit mode.

I will put it as transit mode choice or where do we have the warehouse hubs or we have distribution strategies. Now, adjustments when we need to make here would be to the logistics only. We will call it at logistics adjustments. These adjustments could be we try to adjust the supplier location, we try to adjust the distribution system or we try to decentralize or maybe centralize our warehouses. In parallel to the post processing we need to make the final adjustments here while trying to understand the packaging system and the size of the I would say here the unit size and packaging in the final adjustments.

So, these are all being done so that we have a minimum environmental impact ,that is there are major two essential requirements that is we are trying to take from this slide. I will put that in a blue color. First is implementation of comprehensive planning and scheduling methods. This is first part. This method should be implemented across the entire factory which should be capable of handling any intrications, any changes, any adjustments.

This is first part. Second part or second takeaway from this overall design, the ideas which are put here is adoption of a monitoring and data communication strategies. So, with this discussion on the levels of the manufacturing design and certain corresponding decisions with some of the ideas which are put on this slide, I will have to take a break here.

In the next lecture, I will try to continue and try to connect the different activities of carbon emission. I will discuss on and we will try to see how an overall facility is divided into smaller elements to have a carbon accounting model.

Thank you.