Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 03

Embodied energy and Embodied Carbon

Welcome back welcome to this course on basics of embodied and operational carbon until the last class we were looking at the background of why embodied carbon is so important, what is its relevance to climate change, what is its relevance to greenhouse gas emissions, what is its relevance to the country's commitment in front of the world that it would reduce the embodied and operational carbon. Now, we come to the actual topic which is embodied energy and embodied carbon. So, in this segment or in the couple of segments that we will have from now, we will look at what is embodied energy? What is its definition? What it entails? What are the stages of embodied carbon? And what is embodied carbon? Why embodied carbon is an urgent issue which we need to address? What are the tools that are used to quantify embodied carbon? Embodied carbon along with life cycle assessment. What are the strategies that are used to reduce embodied carbon in built environment? And what is India's framework for tackling embodied carbon? How do we assess embodied energy? And what are the rating systems and embodied carbon? What are the impacts, challenges and future trends in embodied carbon? and what policy interventions are required in India. So, these are the things we will see in this class as well as in the forthcoming class. First, we will see what is embodied carbon and we will go by a very basic definition which has been highlighted by World Green Building Council.

Which says embodied carbon is the greenhouse emission associated with materials and construction processes throughout the whole life cycle of a building or infrastructure. Now this is by far the simplest, easiest and straightforward definition. United States Environmental Protection Agency, it gives a slightly elaborate definition of embodied carbon. It says embodied carbon also known as embodied greenhouse gas emissions.

It refers to the amount of greenhouse gas emissions associated with upstream extraction of building material, production of building material, transport of building material and manufacturing stages of a product's life. Many initiatives to track, disclose and reduce embodied carbon emissions also consider emissions associated with the use of a product

and its disposal too. So embodied carbon does not restrict itself only to the manufacture of the product but it also goes to understand what happens during the disposal of a particular product. So, embodied carbon is the sum of greenhouse gas emissions which are released during raw material extraction, transportation of the raw material, manufacturing of the raw material into a particular product, construction using the product, maintenance of the product renovation of the product and end of life of a product or a system. It encompasses all the stages of the product.

Embodied carbon is reported as global warming potential GWP and is measured relative to the impact of one molecule of carbon dioxide usually lasting over a 100 year time frame. 1 kilogram of carbon dioxide has a global warming potential of 1 kg carbon dioxide equivalent. Whereas, for example, 1 kilogram of methane is approximately 28 kg carbon equivalent. You would have remembered, we have studied this in the preliminary classes of this course, where we saw what is the global warming potential of all four greenhouse gases along with carbon dioxide equivalent of the greenhouse gases. I would like to reiterate that there would be many overlaps as I speak because it is important to bring back certain important definitions so that you do not forget it and so that it is easy for you to recollect the basics and recollect the context of the course.

So, what is carbon dioxide equivalent? Now, if somebody has a currency, suppose you have 100 dollars, 100 euros and 100 rupees. What would you say is the currency you have in hand? It is very difficult for you or it is impossible for you to tell. You can't tell you have 300 (What??) What do you have 300? You can't tell. So, what do you tell? You convert either of the two into any one currency. For the sake of convenience, we use US dollars and convert it.

And then you say, say you have 1.3 USD, you have 1 USD and you have say 0.8 USD. And you add that and you say what is the total USD you have? And that is what is carbon dioxide equivalent. When you say methane, methane what? What impact it has? You convert it into CO_2 equivalent which is between 21 to 28 depending on the literature you pick up from and you convert that and that is the equivalent of greenhouse gas.

Now, let us look at what is GWP or global warming potential. The global warming potential was developed to allow comparisons of the global warming impact of different gases. Specifically, it is a measure of how much energy the emission of one ton of a gas will absorb over a given period of time relative to the emission of one ton of carbon dioxide. The larger the GWP, global warming potential, the more that a given gas warms the earth compared to carbon dioxide over that time period. Carbon dioxide by definition has a global warming potential of 1 regardless of the time period used because it is a gas being used as a reference benchmark gas.

CO2 remains in the climate system for a very long time. CO2 emissions cause an increase in atmospheric concentration of CO2 that will last thousands of years, unlike say, methane. Methane has a global warming potential of 28 over 100 years, with respect to benchmark or rather in comparison to the benchmark carbon dioxide. So, use the same analogy that I gave about the currencies to understand carbon dioxide equivalence and GWP. Let us now look at what all comprises embodied carbon.

Embodied carbon includes extraction of raw materials number one now how will that vary let us take an example suppose you have to manufacture brick what would be the energy required to extract the raw material for the brick the raw material for brick is soil So, first segment will be you add number one. I would write here 1. Energy for extraction of Soil? Yes. Can we have another building material? Can we have aluminum? What would be the energy for extraction of bauxite? Bauxite is the ore, isn't it? For aluminum. So, I am writing bauxite.

So, let us read this. To extract soil, how much energy would you require? Can you just imagine? To get aluminum what do you do? You need to extract bauxite. Where do you get bauxite? What is the nature of bauxite? Bauxite is a porous element. So how do you get a porous compound? From where will you get it? It has the capacity to store water and therefore it is found in forest areas. Because it has water it has trees grown over it.

In order to extract bauxite what would you do? You would clear the trees and then through strip mining you will take out bauxite. Can you imagine what you would do to extract soil for brick? What would you do to extract bauxite from a forest area, from a almost virgin forest area? You go to a virgin forest area, clear the forest, mine for bauxite and take the bauxite. So, for a brick and aluminium product now you have the raw material extracted. But what is the amount of embodied carbon that goes while doing this process alone? For the soil all you need is probably a spade or a slightly high end machine to take the soil and dump it on a truck. For aluminium, can you imagine what you need and what is the consequences of what you do? What is the consequence of digging a particular place for mud? What is the consequences of clearing? What consequence? Environmental consequence.

I am not talking of social and economic consequence for now. Because we are talking of carbon, we will talk restricted to environmental consequences. By clearing the forest, what are you doing to the ecosystem? By taking the, by extracting the bauxite through mining, what are you doing to the ecosystem? Think of all that. And think of the embodied carbon associated with it. Next is transport to factory.

Okay. So, you transport. How do you transport say? You can transport soil. Even in bullock carts. Yes or no? Or you can transport in anything on a tractor trailer. How do you transport for bauxite? That's impossible.

So you again need high end machines. High end vehicle. Can you imagine how much of Carbon, you have already spewed into the environment between a bullock cart and a high-end vehicle, a truck, a lorry for bauxite. Third is manufacture of products. What does it entail to manufacture? Brick.

You need to prepare the soil. Then you need to prepare the soil. You need to add some binder. You need to add water.

You need to mix it. If it's a low end country brick you can mix it manually. Otherwise you use a small machine to mix it. Then you make it into moulds. You sun dry it.

We will stop at this stage. We will go to bauxite and then again come back. Bauxite. From bauxite you will have to extract. From bauxite to aluminum. Aluminum has very high melting point.

So, you have a furnace for it. These sun dried bricks. So, you are using nature now. The sun dried bricks are now fired. What is the, for firing what is the source of fuel you use? Depending upon the nature of brick. It is sometimes straw, husk, sometimes wood burnt, sometimes it is an electric kiln.

You burn the brick. Come to aluminum. You need a furnace. It has a very heavy, very high melting point and you melt furnace. Can you imagine the amount of carbon, embodied carbon in brick and aluminum even until this stage? Then next is Use and maintain in building.

You need to transport. You need to transport the brick. How would you transport the brick? Can be bullock cart, can be a lorry, can be a tractor trailer. Aluminum what happens? You need to take it to a fabricator. It has to be converted into a usable building material. Imagine the amount of energy that goes into it at this stage.

Then next is construct the building. What does it take for you to use brick to construct a building? What does it take for you to use aluminum to construct a building? Then what happens when you demolish that product? When you demolish what happens to brick? It could either go in a landfill or you can reuse it as a demolition waste. What happens to aluminum when you demolish a building? Aluminum is highly recyclable. You can recycle aluminum. But again if you want to melt it and recycle it, the amount of energy

required is very high.

In its actual form it is okay. So this is the brief I am giving with respect to just two materials. You can choose any two materials and imagine what would be the embodied carbon. What would be the carbon dioxide emission at every stage and process of its production? extraction, transportation, manufacture, erection, demolition and recycling. We will look at all these things in greater detail. For now this is an example I wanted to quote.

Let us look at the stages of embodied carbon. The first stage of embodied carbon It's called as upfront carbon. What is upfront carbon? The emissions caused in the materials is production and construction phase. That is from A1 to A5.

That is called as upfront carbon. What does it comprise of? It comprises of raw material supply, transport, manufacture during a product stage. So, upfront carbon is the emissions which are caused during the material production and construction phase of a life cycle before the building or infrastructure begins to be used. In contrast to other categories of emissions listed here, these emissions have already been released into the atmosphere before the building is occupied or the infrastructure is in place. You have already emitted enough carbon dioxide due to the raw material extraction, transportation, After the product is manufactured, you transport it to site and you start installing it in the building.

So, till now the building is not in use. Building is not yet used. Okay, this is where the buildings starts getting used. Then we call it as operational carbon. The emissions associated with energy used to operate the building or in the operation of that infrastructure that is called as embodied carbon, operational carbon. So, this is the operational carbon which entails building use or the product use, maintenance of the product.

When the product undergoes repair, suppose it is a tap. you already have look you looked at the manufacture of a tap so how much energy it uses then you look at use of the tap that's nothing how do you maintain the tap the washer goes off it leaks whatever you have to do you do you repair it then you refurbish it It's not working well. So, I might think of changing a particular part or you replace it completely. So, the embodied carbon up to this stage is called as operational carbon because that is the carbon dioxide which is released when you operate the particular product. Imagine the same thing for another product like a mixie.

A mixie will have an embodied energy from A1 to A5. It will have operational energy from B1 to B5. Then you have what is called as end of life carbon. The carbon emissions

associated with deconstruction demolition This is end of life carbon.

So, deconstruction demolition. Then next is transport from the site. So, how do I deconstruct or demolish the brick or the aluminum? How do I transport the demolished waste? Then how do I process this waste? What do I do with it? Do I powder the construction CWD? Construction waste demolition or do I smelt the aluminum? What do I do? And then fourth is disposal of that product or disposal of the associated waste. From what you get. So, that is called as end of life carbon and then you have beyond the life cycle carbon. So, looking beyond the typical carbon emissions associated with the product's lifestyle is called as 'beyond life cycle.

It's essential to factor in emissions reductions achieved through the reuse or recycling of materials. Additionally, acknowledging the emissions avoided by utilizing waste as a fuel source in alternative process, it is referred to as module D, is crucial. Integrating this module D is very important because it's a consideration is pivotal for optimizing the resource efficient utilization of material during the end-of-life-phase and anticipating upcoming revisions to other standards Reporting module D will become obligatory for product environmental product declaration in the majority of instances. What is EPD? Which has to be declared for every product it is being done now in the european standards it's called as environmental product declaration the requirement will also extend to assessment of buildings so it becomes important that you will have to talk about this in the epd so you need to understand what is epd See, environmental product declaration, it is a short version of life cycle assessment, LCA.

LCA is too much in detail. LCA has commercial names. EPD does not have commercial names. EPD is a short form. And it is generic. It does not take the name of company. So, it is easier to use this communication rather than a LCA report.

So, you are now learning two things. So, LCA is Life Cycle Assessment and EPD is environmental product declaration. So, in a EPD sensitive product information is not what shall I say is not given out which is done in LCA. You can share EPD with stakeholders and things like that what all EPD contains it contains LCA document in a brief results I would say it contains results of the LCA then a proper description of the product is also available then apart from product description the specification is complete specification is available. Assumptions used in LCA study for different life cycle stages that is available.

The rules of calculations are also available. So, all this is available in EPD And that is the future because right now European standards adhere to what EPD says. So, I think we will stop with this and I will summarize quickly whatever we have learnt. Today we had

seen definition of embodied energy or rather embodied carbon energy. We have seen what all, what is the significance of embodied carbon? What all comprises of embodied carbon? With examples. And what are the stages of embodied carbon? Stages of embodied carbon is product stage, which is raw material supply, transport and manufacture.

Construction process stage. Then you have operational carbon. So, today we saw embodied carbon in detail, we touched upon operational carbon, we saw end of life carbon and we saw beyond the life cycle carbon which is going to be the future. If you see this reuse, recovery, recycle beyond the life cycle is going to be important and we are also looking at how for every product EPD is should /would become mandatory in future and you need to look at the product description in detail to understand EPD which is a declaration of every product. It is more like any food. How it's mandatory for everything to be written, what it comprises of and things like that.

Like that for every product, EPD will also become mandatory. So we will stop this class here and stop the lecture here and we will continue this lecture in the coming class. Until then, keep thinking of the embodied carbon of everything that you use in your everyday life.