Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 04

Basics of Embodied and Operational Carbon- Part 1

Hello all. So, last class we saw in detail the definitions of embodied carbon. We also saw operational carbon. We saw what all goes into the manufacture of a particular material in very brief or rather a comparison we saw between brick and aluminum. Today we will continue with this topic embodied carbon versus operational carbon. Because last class we saw embodied carbon, operational carbon, what happens when it is demolished and then reuse.

Now we will see a small comparison between these two. The built environment is a major contributor to global climate change. It is responsible for about 40% of annual carbon dioxide emissions. This carbon comes from two sources, embodied and operational.

I will keep repeating this often in this course because this is the basic and it's very important. Most people are familiar with operational carbon, the carbon used in operating and using a building. Now for example, this comes from lighting, heating, ventilation, cooling, fans, air conditioner, maybe general power usage throughout a building. The operational carbon footprint of a building is the sum of all the carbon produced over the lifetime use of the building which could easily be maybe 60 to 70 years or at least 50 years. Embodied carbon is the carbon footprint of a building before it is in operation, before the building is built or rather immediately after it is built and it encompasses the greenhouse gases emitted during the construction process.

This includes extraction of production materials, transportation of materials, manufacture of materials, construction of material, demolition and retrofitting, end of life deconstruction. So embodied carbon is the upfront carbon that is generated before you actually use the building. Now, what is embodied energy? You have what is called as initial embodied energy and it is the energy required to initially produce the building or produce a product. It includes the energy used for the extraction, the processing and the manufacture of the materials of the building as well as the transportation and assembly on site. Recurring embodied energy is the energy needed to refurbish and maintain the building over its lifetime.

Demolition energy is the energy necessary to demolish and dispose of the building at the end of its life. The cradle to grave embodied energy life cycle does not include the operational energy required to utilize the final product. In other terms, it does not account for the heating, cooling, lighting and power of any appliances that allow the building to be served its intended function. So, the three most common things in construction practices are cradle to gate which is embodied energy of individual building components. To make it easy, let us look at a small example of a toothbrush.

Because that's one of the first things you use every day in the morning to brush your teeth. So, what is a toothbrush made up of? You have a plastic handle. You have a plastic bristles. Think of where this plastic comes from and that accounts for the raw material. So, you have a toothbrush, you use a plastic toothbrush like most and your friend uses Wooden or bamboo toothbrush.

Imagine where the raw material will come for the plastic toothbrush. Petroleum product. Where does petroleum come from? How is it manufactured? How do you get the raw material? How do you get the plastic from it? And when it comes to bamboo what do you do? Just go to a nearby whatever either a forest or a wasteland or any place where lot of bamboos grown and you take a piece of that bamboo. What about even a more vernacular way where they use neem twig. Chew the neem twig and make a bristle out of it.

And look at the bristles of the bamboo, of the plastic toothbrush and the bamboo toothbrush and the third is the neem twig. I hope you know how the bristles of the neem twig is done. They just chew the neem, soak in the mouth (in the neem water or neem which is soaked in your mouth) and thats the end of it. Because it's bitten,(the twig end is chewed) and you get bristles. Look at the embodied carbon of all the three for the same purpose.

Then second is transport. What does it entail to transport the raw material of a plastic toothbrush? What does it entail to transport a bamboo toothbrush base and its plastic bristles? Is there any transportation involved in neem twig? This analogy you take. And third is manufacture. How do you manufacture a plastic toothbrush, a wooden toothbrush and the neem twig? So, this is called as the product stage. Where the product is getting manufactured.

Use the toothbrush analogy for any other product. Any other product of your choice. You can use it for a walling material. Look at the analogy for a walling material or a plaster or a mortar. Walling- you can consider various walling materials.

You can consider various plasters. For walling material I will consider brick, AAC block. For plaster I will consider cement, lime. For mortar I will consider cement, lime, mud, mud mortar. So, for all these materials just imagine the product stage embodied energy.

Let us move to the construction stage. What is the energy required to transport say a plastic toothbrush or a bamboo toothbrush or a neem twig? What is the construction installation process? Similarly, try to have the analogy for the other building material. What does it entail to transport brick which could be locally available and AAC block which may not be locally available and what is the transport for cement And lime, lime could be a locally available material. In fact, it is most of the times and so on. So, you have then use stage.

What is the embodied energy during use of the building? What is the embodied energy required for maintenance? Repair, refurbishment and replacement. four things. This comprises use stage and then you have end of use stage- which is deconstruction, demolition. Can we make it dismantleable? That is the kind of choice you should make. Should it be deconstruction, demolition or should it be dismantleable? Should it what is the nature of transport that you need what is the waste processing that is going to happen and how will you dispose it are you going to put it in a dump field is it going to go into the man landfill or are you going to reuse so that is end of stage so cradle to great gate embodied energy is of an individual building component.

Cradle to site is the energy required to produce the finished product and cradle to grave is the energy consumed by the life of a building or a finished product. Use this analogy for various products that you use in everyday life and for various building materials and you would understand how our choices can influence embodied carbon and greenhouse gas emissions. Now why is embodied carbon an urgent issue? So, we are currently facing a climate emergency as highlighted by the 2018 UN IPCC, Intergovernmental Panel on Climate Change. It depicts a stark contrast between a world with a 1.5 degree and 2 degree temperature increase.

The latter scenario of 2 degrees centigrade could lead to catastrophic climate breakdowns and destroying entire ecosystems. The economic toll of heightened heating and cooling demand is predicted to quadruple by the century's end with some consequences being irreversible. For example, extinction of a particular species, it's irreversible. So urgent action is imperative to transform unsustainable consumption models. The built environment sector responsible for 39% of global carbon emissions plays a crucial role in addressing the climate emergency.

Decarbonizing this sector is amongst the most cost-effective strategies to mitigate climate breakdown. We all can live in a house which is made up of brick as well as AAC or cement blocks. We can equally live in these houses but the carbon impact on the environment is different. So, this sector is the most cost, I mean most easiest to Manipulate in favor of being low carbon. In 2018, aligning with the Paris Agreement, the World Green Building Council launched the net zero carbon buildings commitment.

This initiative aims to inspire climate leadership, urging business and governments to achieve net zero operational carbon at both individual and mass scales. However, it emphasizes that operational carbon emissions are just one aspect of the broader story. According to the Paris Agreement, in order to avoid an irreversible and catastrophic climate change trajectory, average global temperature must not rise more than 2 degree centigrade. Since emissions accumulate in the atmosphere and there is limited time remaining before the arrival of the skipping point, emissions released now are more critical than emissions released later. The majority of a building's total embodied carbon is released upfront.

Upfront means even before the building is built. Unlike with the operational carbon, there is no chance to decrease this embodied carbon once the building is built. There is an urgent need to address embodied carbon now to meet short-term and long-term climate targets. As the global population nears 10 billion, the building stock is projected to double, demanding a transformation in our sector to avert environmental crisis. Failure to do this risks doubling raw material consumption by the mid-century, escalating emissions and climate impact.

Carbon emissions spanning manufacturing, transportation, construction, erection and end of life phases contribute around 11 percent global emission. This is termed as the embodied carbon. Often overlooked, these emissions significantly impact the environment. Upfront carbon emissions occurring before a building is utilized will account for half the carbon footprint of new constructions by 2050, jeopardizing a substantial portion of our remaining carbon budget. Urgent action is essential in this area because it's a huge area of concern.

Let us now look at the embodied carbon, the energy used in the buildings and construction sector and the related carbon dioxide emission. This data is for 2020. You can see that of the total energy that is consumed, embodied carbon, 36% this part completely due to buildings. So, buildings consume 36% of embodied carbon and what are the emission percentages? If you look at this 37% of GHG emission comes from the building industry. If you and I as architects make prudent choices of building materials, respecting climate, context and the environment, definitely this 36% of energy and 37% of emissions can come down.

This is the least we can do in order to support our commitment to a net zero world. And that is why embodied carbon is an urgent issue. Now, let us look at the strategies to reduce embodied carbon in built environment. How can we do this? Broadly, there are a few types of strategies for reducing embodied carbon in buildings. One is we build less, we reuse more by extending the life of existing buildings and materials.

We can build lighter and smarter with less of a given material or floor area to do the same work. We can substitute low carbon materials for high carbon ones. We can procure lower carbon product selection. And architects can encourage reuse, renovation and retrofitting part of all that is complete building or a part of the existing building rather than demolishing and building new ones. Case studies using WBLCA to compare the embodied carbon savings found that building reuse yields up to 44% less environmental impacts than new construction.

That is why LCA life cycle assessment becomes very important. Architects can demonstrate opportunities for design and programmatic flexibility to reduce the indoor floor area required to meet the same program requirements which translates to embodied carbon and cost savings. Architects can encourage reduction or elimination of below grade parking or interior spaces because construction of basements or below ground spaces are extremely carbon intensive. Subgrade construction requires a large amount of concrete which is a carbon intensive material. and it causes carbon to be released from the soil during excavation, both of which can have large embodied carbon impacts.

Structural design decisions such as base sizing, column and beam spacing, member cross sections, lightning slabs and avoiding structural gymnastics like cantilevers and transfer beams etc. can all result in large carbon and cost savings. These strategies require architects and engineers to coordinate to optimize the design along with an awareness by the client. Architects can use WBALCA alongside energy modeling to help assess the trade-offs in embodied and operational carbon for envelope design. Typically, lightweight envelope systems are likely to have the lowest embodied carbon in addition to reducing the embodied carbon of the supporting structure.

Durability is also extremely important to extending the life of materials. Material and system selection strategies can be a little more what shall I say an architect can be more aware. We can have bio based materials what happens with bio based or agro based materials your upfront embodied carbon becomes so less immediately. Instead of having probably a soil which is a brick or a cement block if you have an agro input into it there are two advantages. The recycling of an agro product is also happening and that carbon is actually embedded in the block which is actually a low carbon block.

So, bio-based materials typically have lower upfront embodied carbon than conventional non-bio-based products and have the potential to store carbon over the life of the building. The availability of bio-based alternatives to conventional materials is increasing. For example, using mass timber, laminated bamboo, wood fiber boards, straw, clay straw, hempcrete, cork, wool, linoleum, then many more. There are so many agro-based products. In addition, some bio-based materials like mass timber are significantly lighter than their alternatives.

Cross laminated timber is another very good viable option in reducing the load and size of supporting structural members. In some cases the load may be decreased enough to allow for preservation of an existing structure unlocking additional savings from building reuse. Very important. These are all small things which normally we do not concentrate on. Refrigerant leakage is one of the biggest contributors to climate change within the building industry.

Architects can collaborate with engineers to use passive design strategies, select systems that use low carbon refrigerants and encourage clients to adopt building management practices to mitigate refrigerant leakage and ensure 100% refrigerant recovery. Selecting an insulation that balances operational and embodied carbon trade-offs is key to achieving a total carbon balance for building. Generally, plastics, petrochemical based insulation rather than nature based or agro based will have much higher embodied carbon. In particular, architects should avoid specifying HFC containing rigid polyurethane spray foam, sealants and XPS products that are being banned or significantly restricted in Canada and a growing number of United States. Design teams should consider material reuse opportunities.

Wherever possible, do not demolish and send the products to landfill. Try to reuse as much as possible. You can work with the building owner to reuse materials on site or from other properties from the same owner. Select salvaged materials. Select refurbished materials like furniture that can have longer lives when refreshed.

Architects and engineers can collaborate to detail structural and envelope connections that can be easily disassembled and reused in future buildings. We need to have adaptable buildings. We need to have buildings which grow with our lifestyle. Where possible, avoid lamination or addition in assemblies such as composite decks or hybrid mass timber and concrete assemblies that prevent disassembly and reuse. Architects and interior designers can collaborate to minimize finishes where not required for functional performance and select refurbished carbon storing or otherwise low carbon finishes.

Particularly in spaces with high occupant turnover and frequent interior fit outs where interiors add up to a large portion of embodied energy in a building's lifetime. Designing and specifying materials with end of life in mind increases the likelihood of reuse and it reduces or eliminates end of life emissions from demolition, transportation and waste processing. Architects can avoid materials that could be difficult to recycle or reuse. This will happen if initially itself the architect has designed the building keeping in mind its disassembly and adaptability. Avoid coatings, adhesives and other composite connections that could prevent recycling.

At a minimum, architects can use template language to incorporate requests for EPDs into their specification as a part of submittals. Without knowing what has gone into the material, why should an architect use that material in a building? Let the architect, the client, the contractor, everybody knows what goes into making of the building material in detail. For products where EPDs are more widely available, architects can integrate embodied carbon limits into the performance requirements for a product, requiring an EPD to document compliance with an embodied carbon limit. Concrete mix design has a huge impact on embodied carbon. Architects should collaborate with structural engineer and contractor to ensure that reducing embodied carbon in concrete is priorities.

So, what are the strategies? Using performance based specification rather than prescriptive requirements. Minimizing the volume of Portland cement by replacing Portland cement with type 1L cement, fly ash, slag and other supplementary cementitious material allowing for longer cure times specifying strength at 56 days instead of 28 days. to allow more time for strength gain and use other innovative strategies. It is up to the architect and the construction industry to strategize and do what it takes to reduce the increasing embodied energy in buildings. As a developing country, India the demand for new buildings in India is rising.

With new buildings there is more embedded energy and embedded carbon in the buildings. If we are able to follow these strategies we can significantly reduce the embedded carbon and embedded energy in buildings and in the same time contribute to the growing economy. With this I stop my class. And we will continue our next class with yet another interesting topic. Thank you.