Course Name: Architectural Approaches to Decarbonization of Buildings

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Week: 08

Lecture 02

Choice of building materials for carbon neutrality - Part 2

Hello students. So, last time, the last couple of classes, we saw some strategies for low embodied carbon, for achieving low embodied carbon buildings. We saw some of the basics. We will go a little intense into the further on the strategies for low embodied carbon. So, the sequence of what we would study would be probably we will look at material selection strategies for low embodied carbon, the hierarchy of the strategies, then example of material considerations for specific elements, low embodied carbon solutions for building. We would look more into whole building design and one-for-one material substitution, specifications, reduction of amount of needed materials throughout entire life cycle.

Probably we would just mention some of the tools for implementation, but not get into too much detail because it becomes a little advanced. But I wanted you all to at least know these terms and therefore, I have included this in the contents and those are the current tools for implementing. How do you assess? How do you measure it? So, the tools for implementation there are some of these they are called as Athena impact estimator for buildings, the carbon smart materials palette, embodied carbon in construction calculator that is EC3, ECCC and therefore EC3 and one click LCA. But we will not go into too much depth or even any depth of these tools.

But I want you all to know that some of these tools are available. So that if you are interested you can go ahead in trying to explore and use these tools. Now we had already seen how material selection strategies for low embodied carbon, how that can have an impact. Now, we already know that the construction sector has been proven to be one of the contributors to the increase in carbon dioxide and other greenhouse gas emissions also. Now, carbon emissions accordingly need to be managed by enhancing the use of low carbon building materials in as many construction projects as possible.

To enhance the use of low carbon building materials in construction projects, every construction professional plays an important role in monitoring and selecting the best materials for the project. All this happens at the early design stage and therefore you have the power to intervene at that stage. Embodied energy has been emphasized as the energy that occurs based on the building materials and the techniques used in the construction. Now minimizing the embodied carbon footprint of buildings is crucial for achieving true sustainability in the construction industry. Now this involves careful selection of building materials prioritizing those with inherently lower carbon content.

How does that happen? This is a recall class and recall of last few couple of classes. How does that happen? One of the thumb rule is that you need to use natural products and that will lead you to have components which have low embodied energy low embodied carbon and sequestered carbon will be high in those products. You should employ best practices throughout the material life cycle. Now, let us look at a small breakdown of key strategies in the forthcoming slides. We have already seen that reinforced concrete frame structures, they are used in constructing a building.

While for claddings and openings, we use glass and aluminium. These are our conventional material choices. Materials such as aluminium, steel, concrete and bricks, they have high embodied energy. What role do you have in lowering the embodied energy of that building by using alternate materials. That is something you have to think.

But let us look at the other strategies to come. Now let us look at the hierarchy of strategies. Now, reduced material use is a very important strategy. We have already seen this that if we need to reduce our building material usage, we will have to go for very impactful strategies and optimize the design to minimize the total materials required. That has a direct implication on build less, build smarter.

This ranges from questioning the necessity of building something new to optimizing the setup and location. You need to renovate existing assets rather than construct new ones or mix and optimize uses rather than plan for single use. And there are three strategies to do this. One is modular construction. Off-site production of parts results in reduced emissions and work disruptions which help even in the efficiency.

So, what you do is you need to know pre-cast or pre-construct components in a particular place and if you do it n mass then the savings due to multiple transportation of materials and even construction processes gets reduced. And therefore offsite production of parts and bringing it onsite for its erection is an important strategy. Controlled dry environment of modular construction can save water consumption. Now, the way curing is done on a particular building which is cast in situ is very different from curing that is done enmass or in a factory. You can save a lot of water.

It allows scrap and other materials to be recycled which reduces waste and which results in less embodied carbon consumption. So, with modular construction and prefabrication, a lot of energy can be saved. Next is structural optimization. Do not use more than it is needed. The spacing of columns, the size of columns, all these need to be optimized- optimized not only for its structural strength, but also for its functionality.

And you can use softwares to optimize their sizes and their location. What I mean is, suppose columns are needed at a particular place, suppose you need columns at a particular place, do not double guess and have columns at ___meters or x meters. You need to use appropriate tools to understand whether it is sufficient to have columns at x plus x dash meters distance. And that will save a lot of energy. Also, what is the functional grid size? Whether it is x or x plus x dash.

So, you need to optimize on both of this. For that, software along with your understanding of the functions to take place- both of it can be combined and we can arrive at an optimized dimension of the structural element as well as the placement of the structural element. Then, let us look at multifunctionality. So these are design elements to serve multiple purposes. So when you have a window, when you have a window sill, you can consider the purpose of the window.

For example, if you have a window which is placed. Glazing which is placed towards the inside. The inside will be flush, but at the same time -suppose you have a window which is placed like this, you can use this space. This can act as a multifunctional space too. So, you need to look at design elements to serve multiple purposes.

So, this window will give you some kind of purpose for lighting, ventilation, and also some kind of personalization of spaces which is needed. Whereas this option A will not have personalization of spaces as against option B. Now, how using low carbon materials, how do you select materials with inherently low embodied carbon? So, building with lower carbon materials has the potential to significantly reduce a building's embodied carbon. These options include using low carbon concrete or even alternate structural systems, like using mass timber or hollow core blocks. Using low carbon materials includes that you select materials which inherently have low embodied carbon in it by virtue of its source from where you extract or manufacture.

What are the thumb rules or key of doing this? First is you use renewable materials. If you want to have low embodied carbon use renewable materials such as timber or straw, bamboo, cork, wool etc. Now these have lower embodied carbon compared to non-renewable materials. What are renewable materials and non-renewable materials? We will see later during the later courses and later classes. Next is considered recycled content.

Now this reduces carbon footprint compared to virgin materials. Now you see slowly I have introduced another terminology carbon footprint. And that is my job to instigate you to learn more and more about low energy, low embodied energy, low embodied carbon emission, low carbon footprint, all to achieve decarbonized environment. So, recycled content reduces carbon footprint compared to virgin materials. Use locally sourced materials because you minimize a lot of transportation emission.

Diesel is a major contributor to greenhouse gas effect. Right from its manufacture to its use on the road, it contributes a lot to the greenhouse gases, or its global warming potential is very high. So, using locally sourced materials will minimize your transportation emission. For example, instead of a XPS insulation, alternative insulation can be used which will have low embodied carbon. Now steel sourced from an electric arc furnace and made with high recycled content will have a lower overall embodied carbon as compared to steel which is got first time.

Then you can also consider design for reuse and disassembly. That is you adopt the principles of reuse including renovating existing buildings, using recycled materials and designing for deconstruction. So as and when you want the building to be reduced in scale you can deconstruct it. Now, all this and the specification of low to zero carbon materials and sequestered carbon including the design for carbon sequestering sites and the use of carbon sequestering material will lead to use of low carbon materials. So, how do you actually know when you go to a place, and you now want a low carbon material? How do you do that? First is see if it has renewable material.

How will you see? So, look for environmental product declarations, EPDs. Now this is something like when we take a food packet or a biscuit packet the ingredients are listed on it. And you also have a green dot indicating it is a vegetarian and a red dot indicating it is a non-vegetarian meal. Similarly all products should have environmental product declarations and in that declaration just check how low carbon that product is. And that will be directly related to how much renewable material it has, what component of that material is recycled and what is the source of that material.

Now, example for material considerations for specific elements. These are very generic specifications that I am telling you. When you have to build a foundation, try to consider recycled concrete or used rammed earth or used stabilized soil. So, all this will further reduce your embodied carbon.

For walls, opt for timber framing. Use straw bale walls instead of burnt brick walls wherever it is possible. You can have insulated concrete forms with recycled content or you can use cross laminated timber, CLT which we saw last class. For roofs you can use timber trusses, you can use metal roofs with recycled content or green roofs. Flooring can comprise of having timber or cork or recycled flooring or bamboo flooring or linoleum flooring. So, all these can be options for flooring.

For windows and doors, select high performance, thermally efficient options which have recycled content in them. If you need to insulate a building, say in cold climates, you need to insulate buildings, you use natural materials like cellulose or sheep's wool or hemp. You can use these to insulate the buildings. So, your material choices and considerations have a very important role in reducing the embodied carbon. Now, let us briefly see the low embodied carbon solutions for buildings which can be broken down into various categories.

So, building a common understanding of these solutions and strategies to reduce embodied carbon in buildings is a critical first step to testing the economic value and potential of low embodied carbon construction. Low embodied carbon solutions, these can be broken down into some parts. First is quantifying the embodied energy. That can be done through life cycle analysis. We will not go into depth of this because I had already told you that I just want to introduce these terminologies to you so that if you are further interested you can pursue this out of your own choice.

Otherwise, these are slightly heavier topics to deal with. So, life cycle analysis of building design options, it is a game changer to address embodied carbon. It quantifies and compares embodied emissions and allows planners and architects to compare options for design and material. So, you have first hand information of which material you should choose so that you end up with a low embodied carbon building. Whole building design yes it is a very important aspect.

Initial decisions that affect the fundamental design of a building to reduce embodied carbon while meeting the functional requirements of the project. One for one material substitution is the basic principle is replacement of one material with another having a lower global warming potential. This is done by reuse of building parts and elements, utilization of recycled materials, substitution for bio-based and raw materials, use of innovative materials with lower environmental impacts. We can design for deconstruction and use of recyclable materials. Direct placement of one material with another that will meet the functional requirements of the original design while having a lower global warming potential is a great situation where your functional requirements are met with your structural requirements and yet, at hand, you have a building which is low in carbon.

And it's great for the environment. Now, whole building design solutions can drive the greatest embodied carbon savings. However, material substitution and specification can also result in substantial embodied carbon savings. Especially when these solutions target carbon intensive materials such as steel, concrete, glass, aluminum, and plastics. Specification of the component or the building material that you use is an important category. Establishing a value or limit for a material characteristics that will dramatically reduce embodied carbon content.

Reduction of amount of needed materials throughout entire life cycle. Now the strategy of reduction of amount of needed material is further broken into the other subcategories. That is optimization of layout plan, how big you want your building to be. Optimization of structural system, where should the columns be located, at what distance from each other, what should be the size of the column. And optimizing this structural system size and location with respect to structural needs as well as functional needs.

Having a low maintenance design. Per se your choice of building materials itself should be such that it should require less maintenance Flexible and adaptable design. So that as the situation changes or family becomes big, you are able to increase the size of the house. Or for best example is COVID times. During COVID times, our houses were not equipped for work from home culture or study from home culture.

And people were really struggling with spaces. But if we have flexible and adaptable design. Then it would have been so much easier to adapt or to make a house adapt to that condition. And enable work from home or study from home. Then we need to and also during COVID times another thing that came in was hygiene. So, flexible and adaptable design will go a long way in reducing embodied carbon by us not trying to alter the buildings.

The components service life optimization. So, whatever component you use it should have a longer life and at the same time it should also follow all of these. such as being low maintenance or being flexible and being adaptable. So all these will go a long way in having a low carbon house. I had told you I would just brief you about this quantifying embodied energy or carbon just with the help of the life cycle assessment. It is also called as LCA and it is a very well known methodology to assess the impact on the environment over the life cycle of a product, process or activity from cradle to grave which helps in tracking down the carbon so that we can take necessary decision.

Now emissions from embodied energy, this includes material extraction, transportation emission, processing emission, manufacturing emission, construction emission, maintenance emission, repair emissions, replacement emissions, refurbishment emissions, deconstruction emissions, waste processing emissions and disposal consequences. Embodied emissions for example, cement is produced through the decarbonization of limestone and this chemical reaction emits carbon dioxide while wood absorbs carbon dioxide during its growth. So, whole life emissions is the sum of embodied emissions and operational emissions from energy consumption for the operation of the building and its appliances over the entire life cycle. There are n number of tools that have developed in order to track LCA.

had already told you what those are in the introduction. One is the Athena, another is the carbon smart materials palette and so on. Since we don't intend to dwell too deep into this, I am not going to discuss much on these tools for now. So, When we look at whole building design, the strategies to reduce embodied carbon exist at every stage of the design process from pre-design, site selection to occupancy. Minimizing the overall quantity of material used in a building, especially high embodied carbon materials such as concrete, steel and petrochemical based insulation products can significantly reduce the overall embodied carbon of a project. Its impact is also shown in designing for additional levels of structural efficiency and material savings.

This can yield compounding efficiency, while lighter structures reduce material quantities as well as requirements for foundation. This can directly result in material cost savings. So, the key consideration is that tracking embodied carbon in terms of kilograms of carbon dioxide equivalent per square foot is key to quantifying the benefit of material quality reductions. Structural engineers often design for efficiency automatically based on economics but because they work within the framing scheme shared by the architects or engineers and architects also need a collaborative approach to achieve deeper savings. Implementing these strategies falls under the responsibility of numerous stakeholders and requires a level of collaboration beyond standard practices and it is critical that the project owner brings together the architect, engineer, energy or sustainability consultant, the contractor if possible and other major stakeholders at the outset of a project to establish roles and responsibilities and set frequent check-ins throughout the design and construction process.

If all of these people come together with a very positive mindset, it is only a question of time before we have a decarbonized India. I will stop with this and we will continue next class. Thank you.