Course Name: Architectural Approaches to Decarbonization of Buildings

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Week: 03

Lecture 02

Factors of Embodied energy calculation

Hello everybody. So, last class we saw the initiatives taken by Indian government or initiatives happened in various organizations in India, which are working on trying to give a voluntary building code by virtue of following it, one will be able to design a low embodied carbon and a low embodied energy building. Now, after seeing that let us move on to assessing embodied energy in a very broad manner. We will not get too much into the detail. We will also see the embodied energy of materials to understand the intensity of embodied energy in various building materials a little in detail. So, this segment will concentrate more on embodied energy of various building materials.

Whereas, the energy used in operating a building can be really measured because you have either a common meter which will measure all the energy consumed by various appliances Or you have thumb rules put on various appliances which tell us how much energy that particular appliance is consuming. But the embodied energy inside a structure is very difficult to assess. In a way it is hidden energy. This energy use is hidden and it depends on where boundaries are drawn in the assessment process.

For example, whether you should include the energy used to transport the materials and the workers to the building site. Or you may even include the material. Will you include the embodied carbon that goes into transporting the workers on the site, for erection of the building? Just the materials for the construction of the building shell or all materials used to complete the building such as bathroom, kitchen fittings, driveways, outdoor paving, lighting, outdoor site lighting, benches and seating in the lawns. The upstream energy input in making the materials such as factory lighting, office lighting, the energy used in making and maintaining the machines that make the materials. The embodied energy of urban infrastructure such as roads, drains, water and energy supply.

Should we include this or should we not include this? In which all component should we include this? In which all component should we not include this? So, there are many boundaries which we have to set when we start calculating embodied energy and that is a

real challenge. The gross energy requirement is a measure of the true embodied energy of a material which would ideally include all of the above and more. In practice, this is usually impractical to measure. Let us just have a look at the carbon dioxide emissions from 1751 to 2017- region wise. Now, it must also be recognized that India has contributed little to climate change historically.

The Intergovernmental Panel on Climate Change, IPCC's 6th assessment report clearly noted that South Asia's contribution was only about 4% of historical cumulative net anthropogenic emissions between 1850 and 2019. Even though the region now includes almost 24% of the global population, not to mention the abysmally low per capita global emission of that region. North America and Europe contributed almost 10 times more to global cumulative emissions in this period, though they represent only 13 percent of the global population. From this graph, you can see that the carbon dioxide emission of Southeast Asia is by far less than that of either Europe, North America and Eastern Asia. Clearly indicating that the per capita consumption would be very very less.

Now, if you look at embodied carbon of building materials You can see that the embodied carbon of aluminum is the highest. Fiberglass comes next. I am not mentioning about brass, lead and zinc because of the less volume of material that we use comprising of brass, lead and zinc. However, Steel is an important material which is used in larger quantities. Cement is one material and glass is another material.

The embodied energy of stone, straw, bricks is quite less. of timber is also quite less, but you cannot look at the embodied carbon of building materials only in isolation. You also need to look at the environmental repercussions of using these materials. For example, the embodied energy of sand is very very less, but if we start using excessive sand just to prove that the building is low embodied carbon it is going to harm the environment aggressively. So, you need to have a balance and understand energy and environment together.

A thorough examination of data sources ensures the development of models with the best available data. Whenever feasible, here we are talking of data of embodied energy and global warming potential results for Indian construction materials database. Now, this whenever feasible data on Indian production processes are prioritized for technological and geographical accuracy. When Indian specific data is lacking, European production process data is used. This is adjusted for Indian production conditions.

Likely technological differences between Indian and European production are assessed and discussed with stakeholders to maintain data representativeness. All key data sources in material model development are referenced with information on input materials or

fuels provided. Data confidentiality constraints especially from the GABI database may restrict licensing unit process data or individual inputs outputs for some sources. Hence, what you see as data from the Indian industry may not be a result of research exclusively got from Indian industry, but it may be data which is extrapolated based on the data that is available in any other country. The extrapolation aspect can bring in minor errors, but the errors are too minor for us to completely neglect the data.

Representativeness of the data for temporal perspective- So, lifecycle inventories are crafted using the latest primary data from reliable and representative sources. If adaptation of regional data is necessary, the most recent available secondary data is employed to develop the lifecycle inventory. There are also technological considerations. The approach aims to mirror the spectrum of technologies pertinent to India, especially for materials like bricks, where the choice of technology significantly impacts product energy. For example, the nature of fuel used to burn the brick will determine its embodied energy.

Whether it is a high-end kiln, whether it is just a rural kiln, the nature of fuel that is used, all that will determine. So technological considerations must be incorporated. Geographical alignment is important. Life cycle inventory models are designed to be reflective of product consumption in India. In cases where the product is typically imported, the production geography in the data set aligns with the country of origin or source mix from which the product is imported.

Based on these extrapolations, the embodied energy and global warming potential results for Indian construction's material database is being evolved. Having come to this, if there is a better way of working this out, then this will be replaced with those data. As of the data we have, you can see that Aluminum extruded profile has a global warming potential of 33 kg carbon dioxide equivalent. All these high numbers of GWP relate to aluminum in some form or the other. No other material comes that close to aluminum and the ones which are low, low on global warming potential.

Straw bale is minus 1.4 and rammed earth is minus 0084. Plywood which is also largely from waste is minus 3.1 and cellulose insulation is minus 1.1 based on how it is manufactured.

Air dried sawn timber is also minus 1.1. Aggregate and crushed stone is 0.0090 almost close to 0. So, you can see and also you can see that embodied energy and GWP is more or less correlated.

More the embodied energy more is the GWP and more is less is the embodied energy

less is the global warming potential. Based on this data and the quantity of building material that is to be used in the building, we can make the right material choices to ensure that our building is moderately, embodied energy is moderately low and has global warming potential is also low. Let us now look at the key principles for selecting low embodied energy materials. No product or material will be perfect in every respect. As an architect, we have to consider a wide range of information and possibilities and then try to select the best solutions.

The best solution will be a combination of 'How much is the global warming potential?' How much is the embodied energy and how much is the quantity of the material used? Source heavyweight materials locally. So, heavy materials like stone or aggregates and bricks should be purchased from local quarries and manufacturers because of the high amount of fuel required to transport heavy materials. source lightweight materials globally the proportion of embodied energy that is linked to transport is much smaller for lightweight materials for example an aluminum or a pvc especially when compared to the energy use in their manufacture Many lightweight construction materials compensate for the embodied energy gained during manufacture by saving energy in the building once installed. For example, the aluminum foil used in insulation products save lots of energy by reducing heat loss. So, aluminum is not to be demonized after all.

Because the amount of heat loss that it saves overpowers the embodied energy it actually consumes. Source materials with a high potential for reuse and recycling. The number one material that will go into recycling is aluminum. It's a very good material when it comes to recycling. The embodied energy that remains trapped in materials at the end of a building's life should not be wasted by sending the materials to landfill.

Now, let us look at the policy interventions required in India. To enhance emissions reductions throughout the life cycle of building and infrastructure, It is proposed that key actions for central and state governments as well as national bodies must be taken. And certain recommendations have been given. One is operational carbon in building regulations. The national bodies such as Bureau of Indian Standard should enhance existing building codes like the NBC National Building Code to address operational carbon from the outset of new building design.

It must introduce metrics that measure building performance through carbon emission alongside traditional energy consumption metrics. State government should develop comprehensive guidelines for retrofitting existing buildings while emphasizing passive measures. The operational carbon management must also be mandated and regulated. Under this, mandate the annual measurement and reporting of energy use and associated emissions for large non-residential buildings at the state level. So, energy intensive

buildings must be monitored continuously or periodically.

Consider implementing fiscal incentives at the state level for building owners and tenants to encourage efficient management thereby reducing energy consumption and carbon emissions The third way is to address embodied carbon through building regulations Firstly, a national standard setting body such as Bureau of Indian Standards should establish a unified methodology for assessing and reporting embodied carbon in new constructions. These must be spanning both -buildings and infrastructure. The whole life carbon assessment offers a detailed methodology adaptable to the Indian context. Subsequently, the authority should enforce the measurement and reporting of embodied carbon in all sizable construction projects utilizing the established methodology. Introducing maximum limits for embodied carbon, especially in large projects is crucial.

These limits verified at both the design and post-completion stages should align with the science-based climate trajectories progressively increasing over time. Establishing a national database and reporting platform which is say akin to reliable product level carbon data is essential and requires governmental support to mandate. This also ensures transparent digitally submitted results accessible to the public and we can actually see that when we are able to bring in some kind of a mandated measure into quantifying operational carbon, embodied carbon and embodied energy specially in energy intensive large buildings Then there is every chance that we are reaching towards a carbon neutral India. And that is the main aim of getting into a carbon neutral India. So, today's class was a little heavy because it was related largely to policies.

It was related largely to what can be done and what could be done, what is in the pipeline. So, the summary would be that the government is has its own plans in place to adhere to and respect to the commitment given in the COP and based on that number of bodies are working parallelly. There are many compliance codes. There are many rating systems. All of these today are voluntary and not mandatory and yet they are working towards going carbon neutral and reducing operational energy.

With this I will close the session for the day and we will meet again for another interesting topic. Thank you.