Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 03

Operational Energy and Operational Carbon - Part 1

Hello friends. So, last class we had seen about the embodied energy and embodied carbon. what are its implications on global warming, how these contribute to GHG greenhouse gas effect and why is it even a concern. We also discussed what is the likely role of architects, designers, civil engineers, all stakeholders in the construction industry to do our part to reduce the global warming through reduction in use of low embodied materials, be little more aware of the materials that we use so that the GHG emissions get reduced. Now, after the building is built, during the course of building the structure, we need to focus on embodied carbon based on the embodied energy of the building materials. Once the building is done, what happens and how is the consumption of electricity or consumption of any of energy resources, how does it impact GHG? We will see all of that in today's lecture, which is operational energy and operational carbon.

So, in this lecture we will discuss about what is operational energy and operational carbon in a building's life cycle. The current global and Indian scenario of environmental impact during buildings operation will be understood and compared with the impact of embodied carbon. We will be learning about the factors that influence the operational energy and how we can reduce it. The policies for reduction in impact along with benchmarks, audits and standards which will now reduce the operational energy will be examined.

Further, we will discuss the case studies of buildings with reduced operational energy and operational carbon than the conventional buildings. The basics of carbon offspring will be introduced and the challenges to reduction in operational energy and operational carbon will be dealt with, with the possibility of future trends in the operational energy and carbon reduction. Now, we will see about the operational energy. The energy used for daily building operations after the construction throughout the building's life cycle that is referred to as operational energy. Now, what all are the reasons for which energy will be consumed in a building after it is built? This can be due to lighting load, heating and cooling or heating and cooling.

as well as the operations of appliances and the systems that we use inside the building. For example, it could be if it is a residence, it could be the refrigerator or the mixie or the rice cooker or the water heater. If it is offices, it could be the computers and lighting, all the lighting fixtures and so on and so forth. And buildings account for the sizeable amount of the world's energy demand, making them important contributors to global energy consumption. Since operational energy directly affects environmental sustainability, operating costs and the overall efficiency of the structure, it is imperative to comprehend it.

Annual operational energy is calculated as the annual energy consumption divided by cross floor area in meter square. In addition to saving costs, Efficient operating energy management and reduction are essential for reducing carbon emissions and promoting environmental sustainability. Several strategies including the integration of renewable energy sources, the use of energy efficient technologies, the optimization of building systems and the emphasis on occupant behaviors are employed in the management of operational energy. RIBA has set targets for reduction of operational energy by 50% by the year 2025 and by over 70% by the year 2030. These programs aim not only to lessen a building's carbon footprint, but also increase its worth and durability.

Now, what are the ways in which the operational energy can be reduced? We will see in the forthcoming classes. But just for a perspective, as we have already seen, we can integrate renewable energy sources in the building because of which the load on electricity requirement from the grid can get reduced. So, solar panels can be used for various things like water heaters or computers, charging the computers and laptop. And then we can have energy efficient fixtures. whether it is in the form of lighting equipment or we have star rating appliances that can be used. Air conditioners are star rated, Refrigerators are star rated.

A 5 star rating of an appliance means it is more energy efficient as compared to a 4 star and 4 star is more energy efficient appliance as compared to 3 star and so on and so forth. Then building systems can be optimized, we can have sensors. So, it will sense the movement of people and accordingly the contraactions will be switched on and doing that will save a lot of energy and emphasis on occupant behavior is very important. We have already discussed how lifestyle changes can have a great impact on energy consumption. When somebody leaves the room, they should promptly switch off the light and the refrigerator door must not be kept open for long.

So, all this will contribute and go a long way in reducing operational carbon through reduction of operational energy. Now, here we see what the operational energy in

buildings is. So, here one can see heating or cooling depending on the on the climate that we live in. Heating or cooling is one. In a residence it can be cooking.

Cooking meaning the contraptions that are used for cooking that can be a rice cooker, it could be a mixie, it could be a fruit juicer or it could be a refrigerator, it could be the normal fridge. Then hot water for sanitary use, which we mean as the geyser. This consumes energy and we can make it energy efficient by having star rated geysers. So, that is the way out. And then ventilation and air conditioning, which we have already covered in heating.

Then lighting loads, this can be indoor, indoor lighting and outdoor lighting. And the various other electrical appliances that we use in our house whether it is the mobile phones for charging and so on and so forth. So, these are, this is the basics of operational energy and the operational carbon. Now, we will look at operational carbon. The quantity of carbon dioxide and other greenhouse gases released by buildings during the regular operations, mainly energy consumption is referred to as operational carbon in buildings.

It assesses the environmental impact and emissions of a structure at every stage of its life cycle. According to a report by the World Green Building Council in 2019, buildings are currently responsible for 39% of global energy-related carbon emissions, 28% of which are the operational emissions from energy needed to heat, cool and power them and the remaining 11% from materials and construction. Reducing the environmental effect of buildings depend critically on identifying and treating the operational carbon. We will further discuss how energy efficient designs, the use of renewable energy, the application of smart technology and emphasis on low carbon materials and the strategies that can help reduce operational carbon. Reducing operational carbon contributes to energy savings and may even raise property values.

So, it is not only in line with environmental objectives but it is also economically advantageous. So, we know that we already know that there is something called an embodied energy and and there is something called an operational energy and there is something called end of life energy. You need to understand that embodied energy is is applicable during the construction of the building and before the occupancy of the building whereas operational energy is all the energy that the building consumes when people use the building so that can range anywhere between 50 years to 70 years depending upon how long the building has been used or occupied Whereas, if we assume the building is being built over a period of 5 years, then the embodied energy is calculated as only for a period of 5 years. But operational energy will continue to be consumed or used so long as the building is occupied and so long people, so long as people continue to use the building. So, when we look at a building in totality, the total

carbon emission by a building will comprise of embodied carbon emission plus the operational carbon emission.

Both together will form what is called as life cycle carbon emissions. And operational carbon emissions, they are, , the operational carbon emission is dependent on how many years the building is consumed along with all the contraptions that are used in the building which consume the energy. So, how much energy is the occupant consuming over a period of the building's lifetime. Now let us look at the global scenario. The world's construction industry rebounded quickly in 2021 after the pandemic and returning to pre-pandemic levels in most major economies.

There has been a noticeable increase in the energy intensive use of buildings since the reopening of workplaces and in hybrid form. At the same time, developing nations demonstrated a clear tendency in the use of more fossil fuel gases in their construction infrastructure. Because of this, the amount of energy required in buildings increased dramatically, rising by roughly 4% to a startling 135 exajoules, which is 10 to the power of 18 joules. This jump was the largest increase in building energy use that has been seen in the last 10 years. There was a big environmental price to pay for this building boom and the ensuing building utilization.

Building related carbon dioxide emissions surged exponentially in fact and it has no surpassed what has been happening in the past. It surpassed the 10 gigaton carbon dioxide threshold in 2021. This statistic showed a significant 5% increase from 2020 and a 2% increase from the previous emission peak observed in 2019. These figures highlight a critical issue. the energy used for building operations account for about 30% of global energy consumption.

This number rises to a startling 34% when one considers the total energy used in the manufacturing of building materials such as high energy intensive materials such as cement, steel and aluminium. These alarming numbers highlight the critical role that buildings play in the world's energy use and subsequent emissions of greenhouse gases. As described earlier, according to World Green Building Council report in 2019, 39% of the world's energy-related carbon emissions are currently attributed to buildings. 28% of which are operational emissions and the remaining 11% during construction which shows 72% and 28% carbon emissions respectively. These results are supported by the United Nations Environmental Programme UNEP and the International Energy Agency IEA and also the World Green Building Council WGBC which together confirm the notable increase in buildings operational energy usage and carbon emissions.

It is vital to take immediate action to curb this trend. highlighting the urgent need for

energy efficient design, renewable energy integration, sustainable building practices and proactive behavior adjustments to prevent further escalation of environmental impact on a global scale. So, When we look at the consumption of energy we can see that residences they consume 20.96 percentage of the total energy generated and non-residential buildings they consume about 8.7 percent The other the buildings from in the other construction industry they totally put together about 7 percent.

And other typologies of buildings which are not extremely energy intensive buildings, they consume about 63 percent. So, but in all of these we cannot we cannot presume that certain building typology is anyways consuming less of energy. and we cannot ignore it, though the focus has to be on energy intensive buildings like offices, malls, commercial complexes, etcetera. When we look at a total buildings energy consumption pattern, we find that embodied energy is it consumes about 28 to 30 percent. So, embodied energy consumption is approximately less than one-third whereas two-thirds or 72 percent of energy consumption is because of operational energy.

We need to know where we have to focus more on when it comes to this data. Now, let us look at the building sector energy transformation potential in India. What is the scope for transformation? According to an RMI report, NIUA RMI report, embodied emissions make up 10%. While operational carbon emissions we are talking of carbon emissions are up to 90 percent in the Indian building sectors emissions whereas worldwide we can assume it is one third and two third. taking into account the improvements made in operational carbon and the embodied carbon that still needs to be improved for efficiency, the operational carbon emissions could decrease to 50 percent and that is where we have a humongous amount of scope that if we are able to improve in the operational carbon then we can improve the operational carbon emissions by 50%.

In India, the building sector accounts for one fifth of the carbon emissions and 33% of its energy consumption. The operational energy consumption in building sector has been experiencing an upward trend in energy usage One reason may be due to urbanization, increased construction activity, growing demand for modern amenities. As a growing economy, there is requirement for more buildings. Globalization has brought in so many offices have come up. And therefore, according to the National Institute of Urban Affairs, RMI report which is that NIUA, National Institute of Urban Affairs report the Indian building sectors emissions are divided into embodied emissions constituting 10 percent of the total energy consumed and operational carbon emissions which account to 90 percent.

This breakdown highlights the significant dominance of operational carbon emissions in the sector's overall carbon footprint. However, advancements in addressing operational carbon emissions and enhancing energy efficiency have been notable. Considering the

improvements made in mitigating both operational and embodied carbon, there is potential for substantial progress. Projections suggest that with further enhancement in operational efficiency and concerted efforts towards reducing embodied carbon, the proportion of operational carbon emissions could potentially decrease to approximately 50%. That is a huge, huge difference we can make.

Imagine if building starts consuming 50% of the current consumption, the amount of operational carbon emissions will reduce drastically and it will have a great impact on the amount of GHG emissions happening and hence global warming. Now, this graph shows the potential of transformation in operational energy use from the year 2020 to 2050. So, if you see, it can be seen that the embodied carbon, the projected figure of embodied carbon, though it has increased, by 50% say. In terms of quantity absolute values the increase is not as much as the requirement for operational carbon. The requirement for operational carbon projected increase is by about 4 times whereas the residential operational is about 8 times.

While using low embodied carbon design will certainly give us a scope for reduction in carbon emissions, low embodied carbon materials will also give us a scope for reduction in carbon emissions primarily through savings of cement, steel and other materials because cement, steel, aluminum are high energy intensive materials. They are, they consume a lot of energy and reduced energy needs through passive design can also be one reason how we can reduce the demand. If we serve needs with efficient equipment further the operational energy can come down. Demand flexibility can bring down operational carbon. Switching to greener sources of fuel is another way.

and falling back on renewable electricity will also bring down our energy demands and operational energy demand and hence operational carbon emissions. Therefore, we will be able to mitigate significantly embodied carbon emissions by the year 2050 if we follow low embodied carbon design, low embodied carbon materials. reduced energy needs with passive design, if we use appropriate energy efficient equipments, if we are able to switch to greener fuels and if we fall back on renewable electricity. We can also see that challenges persist in reducing carbon emissions from buildings due to the dominance of traditional energy sources which relies largely on coal and we have seen in our previous classes how falling back on non-renewable energy source such as coal will increase the carbon emissions. inefficient infrastructure, rapid urbanization and varying levels of economic development across different regions.

So, India has been implementing policies and initiatives which are aimed at promoting energy efficiency and reducing carbon emissions in buildings. The government has introduced programs in incentivizing energy efficient construction and retrofitting

existing structures with improved sustainability which we will be discussing in detail in the further class or during the further course of this class. Now, if you look at the urban residents and if you look at the energy consumption pattern or rather the areas where energy or rather the contraptions which consume energy, we can see that air conditioning is one of the most contributing reasons to carbon emissions. And next to that comes is LPG or PNG cooking. If we need to target operational carbon emissions, we need to target reduction in the use of air conditioners.

That is going to be a key. Why do we use air conditioners? Because the indoors are not thermally comfortable. Can we make the indoors thermally comfortable? Yes. How do we do that? Through appropriate design, through appropriate choice of building materials, using bioclimatic principles, using passive, simple passive techniques, if not possible using advanced passive techniques and so on and so forth. But The reduction in use of air conditioner is in the hands of the designer and that is a major responsibility we have as architects and designers. Of course, the efficiency of air conditioner is also another thing which mechanical engineers focus on, but that is for another day.

Now, let us look at the rural residential operational energy consumption projection by the year 2050 in India. We can see most energy is consumed for cooking with wood or the primary source of emissions is wood which is largely used for cooking. And it is also projected by the year 2050, air conditioners and wood along with cooking with LPG gas. All three are going to contribute equally. Which means right now where the load due to air conditioner is very less that is going to increase 4 times or even 5 times by the year 2050 even in rural areas.

And therefore that is also a matter of concern. Which means we can see that air conditioners are the major contributors to operational carbon and operational emissions. And as I had already said, we as architects have a very crucial role in trying to curb, in trying to reduce the carbon emissions due to operational energy through appropriate design. In our next few classes, we will focus on these aspects also. So, today we have seen operational energy, operational carbon, what is the global scenario, what is the Indian scenario and what do projections talk about operational energy consumption in the urban area as well as in the rural area. We will come back with another interesting topic in the next class. Thank you