**Course Name: Architectural Approaches to Decarbonization of Buildings**

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**Lecture 01**

Strategies to reduce Operational Energy

Hello all. If you remember we had stopped with this slide in the previous class. We had just touched upon the strategies to reduce operational energy and today we are going to look at these strategies in greater detail. So, reducing operational energy in buildings I mean can be done with very many strategies. We have already listed the strategies last class. I will just repeat it quickly.

We can use energy efficient building operational and HVAC systems. We can use smart lighting solutions. We can use building envelope improvements. We can have good BMS solutions.

Renewable energy can be integrated. Behavioral changes in education amongst people due to awareness can happen. So also energy efficient appliances with star rating Good star rating appliances will give us good energy efficiency. Conducting energy audits will make us touch base with the reality of how much energy we are consuming through which mode. Now this pyramid figure here shows how at each stage there is a possibility of operational energy reduction.

However, if it is not optimized, it can decrease the opportunity of energy savings at the use stage itself. NIUA report provides us with strategies to reduce operational energy and operational carbon through reduced needs, efficiency and renewable energy supply. Further we can devise strategies to achieve as can be seen in this flow chart. These whole system strategies which are outlined and which we will discuss now emphasize a comprehensive and synergetic approach to reducing operational energy use in buildings. By integrating multiple strategies across design, technology, behavior and policy sphere, it even aims to achieve significant reductions in energy consumption while enhancing building performance and occupant comfort.

So let us look at these strategies now in general and in the forthcoming slides of this class in a detailed manner. So first is the building location orientation and form. So this

provides us with a large opportunity to reduce operational energy. How does that happen? Suppose you have a building which is oriented in such a way that I am taking the examples of two buildings ok. The north is pointing up and so this is the east orientation of building one and I am taking two examples, building 1 and 2 and this is the western facade or western side of the building.

You can see in this building that the western side is shorter whereas In this building, you have a long western exposure and we know that the western sun is very harsh. It's a very harsh sun. intense sun. So, if you have rooms oriented along the west they are going to be like a furnace they are going to be very hot unless you use some other strategies. So, just by orienting the building in the form of one example one instead of example two we can bring in a lot of comfort to the users.

Then let us look at building form. If it is a very hot place and, for example- we will take two forms. One is a square and we will take an octagon. Again, if this is the north pointing up, you can see the amount of surface that is exposed to the direct western sun. Whereas, in this building, the direct western radiation is only for a shorter or the facade is very short there. And all other western sun is only incident which is not direct. So, indirect incident solar radiation always has a lesser intensity. I am not getting into the formula, but this intensity is less and hence form of the building plays an important role. The next factor which could determine is the fabric element design. So, how do you have the envelope design? How do you design the envelope? Then the third factor is air tightness and ventilation.

Whether the building is porous, whether you are providing fenestration or it is a tightly sealed building, whether you are using renewable technology, solar, hydro or wind energy, no, yes or no. appliances and lights and their efficiency and ultimately how you use the building. So, this gives us an opportunity to reduce energy consumption in buildings. Now, let us look at operational energy and carbon at a larger level. So if we look at reducing energy needs then urban scale passive solutions with passive buildings are needed.

So these are the technical solutions we can have. What happens is market penetration of passive strategies will happen and we will start having city cooling plans, integrative passive design hub and indigenous design challenges will come up. Because every place has a very specific climate and you already have buildings of historic importance from which we can learn. And this will give rise to design energy use with intensity and this can result in zero code roadmap. So, reduce energy needs using passive strategies when applied to individual buildings can lead to a zero code roadmap.

While we serve needs efficiently by using ultra-efficient equipment and smart systems, here ratings become important. Appliance and equipment efficiency by type, star ratings which are prevalent now given by Bureau of Energy Efficiency, BEE. Demand aggregation programs and appliance equipment roadmap must be there resulting in operational energy use intensity which will require corporate commitment, finance focus to fund the innovations, government agencies commitment by probably making certain things mandatory. integrated resource plans to create awareness and building performance standards. Now supply with clean energy must have demand flexibility, fuel switching Fuel switching say the example is clean cooking market share, clean cooking access plan.

So, one good example is the 100% solar kitchen at Auroville which cooks which is involved in mass cooking just using solar energy. So, there they have switched to completely green fuel. Then you have clean energy procurement with renewable procurement capacity on and off site, building renewables coalition and building renewables requirement. Some of these can be statutory mechanisms and others are leadership collaboratives and nothing can be done or nothing is possible without the awareness in users. Now, let us look at the first strategy which is building operations.

Now, building operations encompasses all of the tasks required to manage, maintain and operate buildings. This entails keeping up the plumbing, electrical, heating, ventilation, air conditioning and building system configuration. Energy savings should be made possible by operation and management practices, procedures and techniques all while preserving or improving the quality of the internal environment and equipment dependability. Building equipment and systems should be appropriately calibrated and tuned to run as efficiently as possible. Scheduled to run only as needed and periodically checked to prevent performance drift.

only then we can bank on its peak performance. A building's operation and maintenance can incorporate efficiency to help us not only minimize energy use, but also optimize on its efficiency. Building systems and equipment should be regularly inspected to avoid performance drift Scheduled to operate only when necessary and properly calibrated and tuned to run as effectively as possible. It should integrate energy efficiency into a facilities operations and maintenance program and it minimizes energy use and cost without heavy investments.

The approach - tune it up. Turn it off. Check it out. These emphasizes the three key strategies. First is you assess the current practices and implement improvements. Swiftly document changes and track the changes for future energy efficient work.

Next, you optimize equipment use through efficient scheduling and maximum utilization of control systems to prevent unnecessary energy consumption. Third, you revamp preventive maintenance to include energy efficient operations, reviewing schedules, adjusting controls and tracking equipment performance for sustained efficiency. This proactive approach reduces operational energy and enhances efficiency and ensures ongoing energy savings. you look at the gist of what I said now it means first you should have a efficient equipment and building design to reduce the building load energy so all your equipments whether it is AC lighting fans Thermal controls should be efficient.

Stay connected. Two-way communication flow between buildings and external entities is very important. The equipments can be smart. They can be sensing. They can, you should be able to control and co-optimize efficiency.

Be flexible and cater to occupant needs. That is what will make it smart. It should be flexible. It should have the ability to optimize building operations as per occupant needs.

Very important. Endure availability to offset, shift or flatten building load. Next is building envelope. Now, reducing operational energy through the building envelope is crucial in managing a structure's thermal and moisture dynamics. The foundation, roof, windows and walls serve as a bridge between the interior and the exterior environment. and it influences how heat and moisture infiltrates and escapes a building.

The insulating properties and construction quality of the envelope regulate this process. Additionally, the color and optical characteristics of the building envelope impact solar energy reflection and thermal emission. Windows play a dual role by allowing light and solar energy into the structure, contributing significantly to the overall heating load. Passive design strategies are pivotal in leveraging the building envelope for energy efficiency. It emphasizes the reduction of leaks and infiltration.

When the building is completely sealed and air conditioned and it can also emphasize for cross ventilation in climate typologies where cross ventilation is needed -air movement is needed- so it uses suitable materials that can be lightweight or heavy depending upon the climate type. It optimizes materials to offer resistance to moisture and heat flow. Its structure should be designed to absorb and re-radiate the heat effectively. Innovative roofing elements can be employed to combat the heat island effect promoting a cooler environment. So it means we have to look beyond an individual building. We have to look at spaces between the buildings too.

So by focusing on passive design principles and employing materials and techniques that enhance insulation and control heat exchange, buildings can significantly reduce their

operational energy demands and hence reduce the operational carbon emissivity, emissions sorry. So, in this slide you can see that the building envelope plays a very important role in facilitating passive design in buildings. It can reduce leaks and infiltration or enhance cross ventilation as the case may be when I say as the case may be. Reducing leaks and infiltration is important in a completely sealed building, whereas to enhance cross ventilation is very important in a hot humid building, a building which is located in a hot humid climate.

The suitable materials can be light, thin and easy to install or they can be heavy based on the thermal mass, based on required thermal mass required thermal mass The resistance to moisture and heat flow must be there. Yes, either ways the envelope should resist the moisture and heat flow. The shells that absorb and re-radiate heat should be designed; the building should be designed in such a way that it does not allow ingress of heat in a hot or a warm climate. Roofing elements that reduce urban heat island thus, looking at making spaces between buildings more comfortable.

The next one - HVAC system efficient heating ventilation and air conditioning systems they play a pivotal role in curbing power consumption within buildings. That's a very crucial consideration as buildings often account for 40% of total power consumption in many developed nations. These systems significantly reduce operational energy by not only curbing energy uses but also enhancing occupant comfort and prolonging equipment lifespan, consequently reducing the need for costly repairs. The replacements and mitigating environmental impact. Achieving energy efficiency in HVAC systems involves several strategies.

Upgrading to high efficient equipments, optimizing system design and ensuring regular maintenance. Moreover, integrating renewable energy sources into HVAC operations, implementing intelligent control mechanisms, using sensors for buildings and enhancing insulation all contribute to reducing energy consumption and enhancing system efficiency. By implementing these measures, buildings can effectively reduce their reliance on conventional power sources, mitigate environmental impact and promote sustainable energy use while ensuring optimal comfort and functionality for occupants. So having a very efficient HVAC system which anyways heating ventilation and air conditioning systems are energy intensive but if we are able to have these systems which are energy efficient for a layman it means if we can use no well star rated HVAC systems well star rated air conditioning units They are the basic outline for us to understand that the system is efficient.

The system is energy efficient. Of course, the best case scenario is to avoid them completely and rely only on natural sources of energy. But in case we have to use air

conditioners, it is best to use HVAC systems which are energy efficient and they must be maintained properly. Next is using lighting and energy use reduction. Efficient lighting practices offer substantial opportunities for reducing operational energy consumption. Household artificial lighting alone accounts for approximately 15% of electricity usage.

But advancements in lighting technologies can dramatically cut residential illumination energy consumption by 50 to 75%. New developments in lighting controls further enhance energy savings by efficiently managing when and how long lights remain illuminated when not in use. Advanced controls also enable automatic activation of lights when needed. When a person enters a room, automatically the sensors notice this and they switch on the light. These will optimize energy use too and it's imperative to strike a balance between light quality and quantity.

Harnessing daylight where feasible, wherever possible and integrating energy efficient lighting, these components and controls will enhance energy efficiency in a building. Maximizing day lighting, employing task lighting strategically, and regulating ambient lighting will help optimize human visual performance while minimizing unnecessary energy consumption. Leveraging occupancy sensors and employing energy-efficient lighting systems play a pivotal role in reducing energy waste Initiatives like the Department of Energy's Building Technology Program emphasize research, industry collaboration, and advocacy to promote energy efficiency in buildings, offering valuable insights into lighting quality, efficacy, color temperature, and glare. All these will guide for effective implementation of energy efficient lighting solutions. This multifaceted approach, I know it underscores the importance of smart design controls and technological advancement in achieving substantial reduction in operational energy consumption from the lighting sources.

So, the gist is we need to first and foremost maximize daylight. Use of natural daylight must be maximized. Human visual performance depends on light quality as well as quantity. Hence, task lights are very important. What do you mean by task light? Lighting required for a particular task must also be looked at.

When the room entails an activity like reading, there is no need to provide lighting levels of that of a watch repairer. know or a diamond cutter their lighting levels are different their requirements are different we need not give such high lighting levels for an area where cooking is an activity then using energy efficient lighting fixtures first we had the candescent bulb no tungsten filament bulb candescent tube lights and bulbs then We had the, LED. Now, LEDs have come in. So, they are highly energy efficient.

And occupancy sensors are very important. This occupancy sensor becomes more

important because of two aspects. One is lack of awareness amongst people where they would simply leave the lights on and leave the room. But if we install sensors, the sensor will see that there is no movement inside the room for so and so time or when the door is closed for exit then it will switch off automatically or when someone enters the room it gets switched on automatically and therefore, it reduces a lot of energy use. Then so, you should you should look at the various types of lighting and based on that now you can use the lighting for efficient task lighting.

You have to read, provide it only in that place. No need to eliminate the entire room. No need to have ambient lighting when the task is very specific in a particular place. Flood lighting, pole mounted lighting; each in its own place with energy efficient fixture will go a long way in ensuring that we can save a lot of energy. Next is use of renewable energy systems. So implementing renewable energy to reduce operational energy in buildings involves several key tactics.

Firstly, on-site generation through installations likes solar panels and wind turbines help generate clean electricity, lessening reliance on non-renewable grid power. Additionally, coupling renewables with energy efficient technologies such as LED lighting and smart appliances optimizes energy use, cutting overall demand. Employing battery storage system ensures a consistent power supply by storing surplus renewable energy. Integrating these renewable sources into building systems directly supplies energy, reducing dependence on traditional non-renewable sources and fostering a more sustainable operational energy model.

Furthermore, this approach isn't just about generating clean energy. It's a comprehensive strategy. By leveraging on-site generation and efficient technologies, buildings can significantly trim their reliance on non-renewable sources. Incorporating renewable sources directly into building system ensures a consistent and sustainable energy supply. This holistic integration not only reduces operational energy but also sets the stage for long-term cost savings, enhanced sustainability and a reduced carbon footprint, making it a pivotal step towards greener, efficient future for buildings as well as communities.

The government offers extensive subsidies for tapping renewable energy and we should bank on this and try to adopt as much renewable energy as possible, especially in a place like India where there is ample amount of sunlight and all we need to do is tap the energy from this sunlight. Here you can see the mix of energy as on 2010 the reality is that we are looking at 84% as fossil fuels and 16% as no renewable. The government's agenda target is that by 2030 we should have at least 50% as green energy. And now we have the BMS system. Implementing a fully optimized building management system presents a significant opportunity to reduce operational energy consumption by approximately 15 to

20%.

Beyond energy saving, a well-tailored BMS also ensures the maintenance of comfort conditions, elevates indoor air quality, and serves as a crucial platform for managing security, alarms, and remedial actions. In case of say fire, there is a remedial action. The optimization of energy efficiency through a BMS involves continuous monitoring and fine tuning of building systems to align with energy saving objectives. This includes regulating HVAC systems, lighting controls and other energy consuming equipments for optimal performance. Additionally, a robust BMS facilitates ongoing performance monitoring, enabling quick identification and rectification of inefficiencies or anomalies, the occupant well-being and productivity while ensuring safety and security solutions for building assets.

Altogether, an efficiently managed BMS not only results in notable energy savings, but also fosters a healthier and safer indoor environment, making it an integral component of comprehensive energy efficiency strategies for buildings. We have also seen a lot about BMS systems in application or rather its advantages as we had been talking in the previous slide. So it would help us with lighting control and retrofit. It can detect smoke control.

It can be designed to monitor indoor air quality. It can give us some clues on our water management, water usage. It can give us HVAC maintenance services can be mapped and monitored, fire detection and alarm, security and access control. security through digital video monitoring and intrusion detection. So, all of this can be managed with BMS making the building more energy efficient and Then we move on to energy efficient appliances. So, energy efficient appliances they play a substantial role in reducing operational energy consumption within households and according to 1997 residential energy consumption survey appliances and lighting collectively accounted for nearly 45% of total energy expenses and consumed around 27% of total home energy.

While this includes lighting and minor appliances, major household devices such as refrigerators, washers, dryers, dishwashers and stuffs constitute a significant portion of operational energy usage. However, these figures don't encompass the full scope of energy expenses, neglecting factors like water consumption, energy usage and water heating expenses associated with washers and dishwashers. In regions where cooling demands are prominent, opting for energy efficient appliances that help maintain lower interior Temperatures can lead to additional energy savings by reducing the reliance on air conditioning systems. To maximize energy efficiency, it's crucial to select appliances with high energy efficiency ratings, especially for high energy consuming devices like refrigerators and televisions. Additionally, optimizing appliance usage and employing

automatically shut off systems for the appliances such as electric motors and washers further contribute to minimizing energy waste and promoting energy efficient practices within households.

In India, the Bureau of Energy Efficiency puts on a sticker over every appliance. The maximum rating given for any of the appliance is a 5 star rating and the 5 star rating is considered the most energy efficient appliance in that particular category. Less than 3 star rating is almost not available in the markets these days whereas it was available earlier on. And then last we see smart technology. Smart technology emerges as a cornerstone in curbing operational energy consumption through multifaceted approaches.

Real-time monitoring capabilities of smart devices offer instantaneous insights into energy usage patterns and swiftly identifying inefficiencies or wastage within systems. Leveraging sensors and artificial intelligence automated controls enable smart systems to autonomously adjust lighting, heating or cooling based on occupancy level or environmental conditions.

Optimizing energy utilization. The analysis of collected data through data analytics aids in recognizing patterns. It fine-tunes the system and forecasts energy requirements and empowers informed decision-making for energy-efficient practices.

The remote management feature inherent in smart technology allows for efficient control and monitoring of energy systems from remote locations, facilitating effective energy management, identifying high energy consumption areas like lighting, HVAC, or running of motors, and implementing smart technology interventions become crucial. Opting for suitable smart devices such as sensors and energy monitors aligned with energy saving objectives play a pivotal role. Ensuring proper installation, integration, configuration and continuous monitoring followed by optimization and regular maintenance all contribute to maximizing the efficacy of smart technology in minimizing operational energy consumption. And so, we come to the end of this class which is a slightly longer class. But I wanted to complete these entire strategies in one class.

And you can give me the benefit of doubt because the last class was a slightly shorter one. So, in this class we have seen all the strategies that we can adopt for reducing operational energy use. We will meet again next class with another topic of interest.