Course Name: Architectural Approaches to Decarbonization of Buildings

Professor: Dr. Iyer Vijayalaxmi Kasinath

Department of Architecture,

School of Planning and Architecture, Vijayawada

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Lecture 01

Introduction to GHG and the role of buildings in its reduction

Good morning. As first part of this lecture series and this course, we will be looking at the impact that greenhouse gas has on the global warming and how it is related to the course that you have taken. In this lecture, we will cover the basics of greenhouse gases, the factors that influence the greenhouse gas emissions. So, what does it mean? What do you mean by saying greenhouse gas? How are they different from other gases? And what influences these gases to be emitted? What is the global scenario and the initiatives taken due to these greenhouse gases? What does the Indian policy and Indian scenario look like? The strategies to reduce these greenhouse gas emissions that would come only after knowing the impact that these greenhouse gases have on the environment. Does India have policies, regulations and initiatives to control their emissions? Has India given a word to anybody and the world regarding what they would do to control these? The challenges and future trends in reducing these greenhouse gases in the building industry because this course primarily relates to impact of greenhouse gases in the buildings. And finally, we will look at the summary.

So, you can see in this picture, this section it provides information on emissions and removal of main greenhouse gases to the atmosphere and from the atmosphere. Both the earth surface and the atmosphere they warm due to solar radiation. The earth surface absorbs the remaining radiation after it has been reflected. So, here you can see that the emissions, they fall like this.

Some part of the emissions get reflected by the earth while the earth's surface absorbs the remaining radiation after it has been reflected back into space by about one third of it and by the atmospheric gases here by about 20%. The infrared radiation is the result of the energy being absorbed in this way. Because part of this radiation is absorbed by the atmospheric gases, some of the energy released cannot escape into space. What happens as a result? The result is these gases get trapped and a part of the heat entails the atmosphere to become warm. This phenomena which raises the planet's average temperature from minus 18 degree centigrade to plus 15 degree centigrade is essential to

life as we all know it.

The situation is comparable to a greenhouse. where heat is trapped inside and cannot escape through the glass walls raising the interior temperature. Hence the term greenhouse effect and it refers to this phenomena. Basically what it means is greenhouse gases are gases which absorb say when the radiation goes like this the greenhouse gases absorb this heat and what happens because of it the heat gets trapped in the atmosphere so this whole thing it's the heat trapped due to GHG And what does that cause? That causes complete warmth of our atmosphere. So, you have to imagine say a glass bowl in which when heat when it is heated what happens? And this is covered because there is an atmosphere.

There is an atmosphere. So, this becomes warm. And this phenomena is what is called as the impact of GHG on the atmosphere. I will just introduce a little bit about what is GHG. So, what all comprises greenhouse gases? We all know that carbon dioxide is one important criteria, one important gas.

Why is carbon dioxide an important GHG gas? Because almost 80% of the GHG gases is comprised of carbon dioxide. Various sources contribute to the entry of carbon dioxide into the atmosphere. Those are burning of fuels, deforestation, all this solid waste, chemical reactions from the industry. The industry also emits a lot of carbon dioxide. Additionally, synthetic and potent greenhouse gases like hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride, they are released from diverse applications with their high global warming potential nature and it amplifies their impact on heat trapping.

How does that happen? We will see that also. Now, methane is another gas. Now, it is an important criteria. It is an important emission. It arises from coal, natural gas, oil production, transport and now being talked extensively is from livestock.

agriculture and landfill organic waste decay. Nitrous oxides they are emitted from agricultural, industrial and combustion activities which further contributes to greenhouse gas levels. This multifaceted array of sources highlights the complexity of addressing and understanding the different contributors to our climate change. Carbon dioxide enters the atmosphere through burning fossil fuels, solid waste, trees and other biological materials and also as a result of certain chemical reaction which comes from the industry. When it comes to buildings we can if we want to relate it to the building industry we can say cement, iron and steel all these emit huge amounts of carbon dioxide.

Now carbon dioxide is removed from the atmosphere. Or it is called as 'sequestered'

from the atmosphere when it is absorbed by trees, plants as part of their natural biological carbon cycle. Hydrofluorocarbons and all the fluorocarbons, they are synthetic powerful greenhouse gases that are emitted from a variety of household, commercial and industrial application and processes. Fluorinated gases are typically emitted in smaller quantities than other greenhouse gases. But they are potent greenhouse gases not to say the least.

They are sometimes referred to as high global warming potential. You will keep hearing this word GWP quite often in this class. and they have high GWP or global warming potential because for a given amount of mass they trap substantially more heat than CO2. If CO2 can trap 'x' amount of gas then there are certain greenhouse gases that can trap up to 28 times what carbon dioxide can trap. Methane is emitted during the production and transport of coal, natural gas and oil and methane emission also results from livestock and other agricultural practices, land use and by also the decay of organic waste in municipal solid landfills.

Nitrous oxide is emitted during agricultural, land use and industrial activities, combustion of fossil fuels and solid waste as well as during treatment of our waste water. Now, we will see the abundance of greenhouse gases in atmosphere, how it has come up. So, concentration denoting the quantity of a specific gas in the atmosphere is directly influenced by the volume of greenhouse gas emissions. You can see this is from the IPCC report and you can see that over the years you can see in 1850 what is the concentration of CO2 and you can see post-industrial this actually this is the 1920s yeah so this becomes the post-industrial era and what is happening in the post-industrial era in this era where industrial revolution started it is marked significantly by industries such as cement, steel, glass, etc. And what has happened because of that? You can see an exponential rise in CO2 emissions.

So, this is highlighted in the IPCC report. The earth's surface has experienced escalating warmth over three decades, surpassing any preceding decade since 1850. So, before 1850 it was a happy picture when it came to CO2 emissions, but post that you can see that CO2 emissions have undergone a exponential growth. This is primarily attributed to the increasing concentration of greenhouse gases. These concentrations are measured in parts per million and for perspective - one part per million is likened to a single drop of water dispersed within approximately 13 gallons of liquid, roughly equivalent to the fuel tank capacity of a compact car.

So, you can imagine the amount of CO2 that we have been pumping into the atmosphere. Now, if we look at the quantitative information on the other greenhouse gases that is methane and NO2 emission time series from 1850 onwards, again you can see that fossil fuels The large emissions of greenhouse gases it leads to concentrations in the

atmosphere greenhouse gas concentrations of again one part per million is equivalent to one drop of water diluted in about 13 gallons of liquid roughly the fuel tank of a compact car and here you can see how the emissions have been increasing. The emissions due to fossil fuels, cement and flaring have increased at a very steep rate and look at the cumulative CO2 emissions because of fossil fuels and forestry. what was it in 1970 and in 2011- you can see the impact , how many times one two three more than four times there has been an increase in Co2 emissions due to fossil fuels cement and flaring. Whereas due to forestry and land use, the impact has not been that much but what concerns us as architect is a large number of what is flared up here is also because of the building industry.

The building industry has needed so much and therefore this has happened. Now, we will look at the global warming potential and it facilitates comparison between various gases. What is the impact of CO2? What do you mean by the GWP or global warming potential of methane, of nitrous oxide and so on? We will just see that. it is measuring how much energy 1 ton of gas absorbs over 100 years relative to 1 ton of carbon dioxide. So, GWP it is a measurement of how much energy 1 ton of a gas absorbs over 100 years relative to 1 ton of carbon dioxide emission.

Higher GWP signifies a greater warming effect compared to carbon dioxide. This standardized metric aids in assessing the varied contributions of different GHGs to global warming. A higher GWP indicates a more pronounced warming effect compared to carbon dioxide. And this standardized metric assists in evaluating the diverse contribution of various greenhouse gases to the phenomenon of global warming. Now, for example, we see that the global warming potential of carbon dioxide is 1.

But look at the global warming potential of methane. It is 21 times. So, it is more potent. And look at the global warming potential of nitrous oxide.

It is extremely potent. And why this comparison? How are we equating or why are we equating? We will see it in the further classes. Look at HCFs. I do not know whether your generation knows, but the refrigerants in our regular fridge and air conditioners used to be HFCs for a long time. But they already the damage was done here because of all these HFCs. And look at sulfur hexafluoride.

The global warming potential is 23,900 times, compared to that of carbon dioxide which is 1. So, CO2 serves as a reference gas and this is assigned to global warming potential because we measure it against CO2. So, CO2 is taken as 1 GWP and with reference to that other gases are measured regardless of the time frame used due to its role as the benchmark because somewhere you have to have a benchmark, somewhere

you have to have a benchmark. Say when it comes to currency, normally in international trade we have the dollars or the euros. So, one dollar is the benchmark.

What is the currency with reference to that one dollar regarding the currencies of other countries? You have to use this analogy here. So, its prolonged residence in the climate system lasting thousands of years underscores its enduring impact. Carbon dioxide concentrations have increased substantially since the beginning of the industrial era. rising from an average annual average of 280 ppm in the late 1700s to 414 ppm in 2021 and this means there is a 48 percent increase so almost all of this increase is due to human activities and that is the concern. There were always greenhouse gases in the atmosphere but what is the difference now? The difference is that , due to human activity, we have accelerated its increase.

What happens if we accelerate its increase? The global warming gets accelerated. impact of global warming we are already facing in the form of climate change. So, somewhere man himself has, sort of, enticed or instigated the rapid decline in the earth's life and therefore this becomes a concern to us. Now, if you look at the atmospheric lifetime in years, the lifetime of carbon dioxide is 50 to 200 years. Even though methane has 21 percent GWP more than carbon dioxide, its lifetime is about 15 years.

And if you look at nitrous oxide, I mean it has a lifetime of 120 years and it has a GWP of 310. And if you look at the fluorocarbons then that is where it is very risky and dangerous because their atmospheric lifetime is also very very high, very high in the sense- 200 times that of carbon dioxide and the GWP, , global warming potential is almost 1000 or 23000 times more than carbon dioxide. So, having said that, now this shows a representative concentration pathway. It is a greenhouse gas concentration trajectory adopted by IPCC. Four pathways were used for climate modeling and research for the IPCC.

Fifth assessment report which came in 2014. The pathways describe different climate change scenarios. So, it is a model. So, a model has been created and these pathways describe different climate change scenarios all of which are considered possible depending on the amount of greenhouse gas emitted in the years to come. So, from the model it is projected what happens under each of these scenario -what happens under this scenario, what happens under this scenario, what happens under this scenario.

So, the RCPs which are representative concentration pathway originally 2.6, 4.5, 6 and 8.5 are labeled after a possible range of radiative forcing values in the year 2100. The higher values mean higher greenhouse gas emission and therefore, higher global temperatures and more pronounced effects on climate change.

The lower RCP values on the other hand are more desirable for humans, but require more stringent climate change mitigation efforts to achieve them. What is the impact of each RCP is already modelled and scientists have worked out the impact of each of the RCPs. For example, an RCP of 2.6, this is the change in average surface temperature. Here, this is the average surface temperature chain.

Compared to an RCP of 8.5, you can see that the earth is almost boiling in comparison to that. And similarly with respect to precipitation, you can see its impact on precipitation also The actual impacts I am not bringing here because we are not here to talk more on climatological aspects, but we are here to understand the significance of embodied carbon and operational carbon and why did that even come up to understand that you need to know these basics. Now, we will look at the effects of GHGs and the evidence in climate change. As the global mean surface temperature rises, it is virtually certain that there will be a heightened frequency of hot temperature extremes and a decrease in cold temperature extremes over most land areas on a daily and seasonal time scales. Heat waves are expected to occur more frequently and persist for longer duration while occasional cold winter extremes will still occur.

Changes in precipitation patterns will be non-uniform. I am sure everyone who is participating in this course would have experienced this in their place. The local weather phenomena has changed dramatically and in an accelerated manner. The high latitudes and equatorial Pacific are likely to experience an increase in annual mean precipitation under the RCP 8.

5 scenario. You remember what is RCP 8.5 scenario? It is the climate change model where it is projected. And you can already see that equators are also experiencing humongous amount of climate change. Conversely, many mid-latitude and subtropical dry regions may experience a decrease in mean precipitation which means there is possibility of high droughts there while mid-latitude wet regions are expected to witness an increase. Additionally, extreme precipitation events are anticipated to become more intense and What does that mean? There are going to be more floods or there are going to be very heavy downpours and frequent over most mid-latitude landmasses and wet tropical regions. All of this has already started because for the last two years, we are experiencing something similar to this at least down south in areas of Tamil Nadu.

We will see the factors influencing greenhouse gas emissions. Greenhouse gas emissions originate from various human activities. The point is greenhouse gas emissions were already there in nature. Nature also has its own way.

But it was a very natural way. The increase was very natural. But if you see today, the impact of human activities has accelerated this release of greenhouse gas effect. Notably, the highest producer of GHG is energy production. You can see here energy production constitutes 83% of GHG. And you know today your world and my world runs largely on energy.

Right from charging our mobile to the use of air conditioner we need energy. And primarily our energy comes from fossil fuel. Another major reason why GHG increases. highest producer of GHG is energy production through fossil fuel combustion of electricity and heat generation. So, industrial process and product use comprises of industrial processes manufacturing and chemical production they contribute to emission of gases like carbon dioxide and methane and nitrous oxide.

Waste that is generated by humans that also contributes to GHG. As you can see they contribute to 4 percent of GHG. So, transportation primarily is reliant on fossil fuels today, though we are slowly moving towards green transport which is in the form of having electricity. We have agricultural forestry here. Agricultural forestry and land use means agricultural practices, land use changes such as deforestation and waste management including decomposition of landfills, release methane and carbon dioxide.

So, all of these contribute to release of carbon dioxide. And therefore, they also contribute to GHG. This additionally specific industrial activities like cement production and use of certain human made gases in industrial applications such as HFCs and other HFCs like perfluorocarbons they contribute to GHG emissions and their impact we have already seen in the previous classes. So, this is the scenario wherein you can see that energy from fossil fuel contributes most to GHG emissions. If you look at the global scenario and if we look at greenhouse gas emissions by economic sector, then this picture depicts the share of global emissions from various sectors like transport, industry is one, energy, other energy is one and primarily electricity and heat production. This part so much of it is electricity and heat production rather and this is from other energies.

So, here we can see what each sector is contributing to. You can see that the agricultural sector contributes to about 24 percent of GHG emission and you notice that the grid which is electricity and the heat production it only accounts for 25 percent of total emissions both are more or less similar. If we replaced all coal, gas and oil plants with renewable sources, then you can imagine there will be a massive reduction in this segment. Now, out of this you can see out of this 25 percent buildings occupy 12 percent. They are the ones which emit 12 percent of GHG along with the other known things. So, we have what is called as direct GHG emissions and indirect CO2 emissions.

Indirect emissions result from the sector's activities. But they occur elsewhere such as the emissions embedded in products consumed or used by the sector. Now the electricity and heat generation may contribute to 25% and that 25% comes from various sectors. But these sectors are not concentrated on one place, they could be elsewhere that is why we call them as indirect CO2 emissions. Besides you should understand where this energy actually goes in and that is called as embedded in products and we would come to embodied energy, embodied carbon in the later slides. Now, building industry contributes both directly through on-site building construction processes and indirectly through the production of goods like cement and steel.

Globally, electricity and heat production, they mark the highest contributors to GHG emissions which is 25 percent, whereas building industry marks highest indirect contributor to GHG in the form of 12 percent. if you look at the global initiatives and the international processes, how are we trying to cope up with this? Now, United Nations Framework Convention on Climate Change, UNFCCC, this part, this convention created what is called as COP, Conference of Parties and the recently held one was in Dubai which you all know. This is the supreme decision making body of the convention. Now, the IPCC, this is the IPCC, it is the Intergovernmental Panel on Climate Change. The World Meteorological Organization, the WMO and the United Nations, the WMO, World Meteorological Organization and the United Nations Environmental Program, UNEP, they established the IPCC to provide a mechanism for studying the effects of global warming at the government level.

The IPCC is the United Nations body that evaluates science on climate change. Its objective is to provide policy makers with regular scientific assessments of climate change, its impacts and potential future risks while providing options for adaptation and mitigation. It complements the UNFCCC and vice versa so they work in tandem. United Nations Framework Convention on Climate Change, UNFCCC. Every year, countries who have joined the UNFCCC meet to measure progress and negotiate multilateral responses to climate change.

There are approximately 198 parties to the convention. It entered into force in the year 1994 and the 198 countries that have ratified it are called parties to the treaty. The UNFCC is the Rio Convention which is one of the three conventions adopted in the 1992 Rio Earth Summit. It was a very important summit. The GEC model is used to explore various scenarios each of which is built on a different set of underlying assumptions about how the energy system might evolve over time. The COP, however, is the supreme decision-making body of the convention.

All states that are parties to the convention are represented at the COP at which they

review the implementation of the convention and any other legal instruments that the COP adopts and take necessary decisions to promote effective implementation of the convention including institutional arrangements and administrative arrangements. So, COP becomes a very important convention and the key task of COP is to review the national communications and emissions inventories submitted by the parties. So, each country has to give a commitment on how much they have emitted, and how much they plan to or a commitment on how much they would reduce the GHG. Based on this information, the COP assesses the effects of the measures taken by the parties and the progress made in achieving the ultimate objective of the convention.

It meets every year unless the party thinks it's not necessary. But they have been meeting consistently year on year. COPs have created global milestones for the climate movement, setting standards and advancing action, including reducing carbon emissions, accelerating a global energy transition and helping countries to adapt and build resilience to compounding climate issues. So, COPs are crucial in bringing governments together while also mobilizing the private sector, civil society, industry and individuals to tackle the climate crisis. Now, we will just see a few of these initiatives.

We will look at what Kyoto Protocol says. Now, Kyoto Protocol was COP3, Conference of Parties 3 in 1997. So, it was, , the COP started way back. The Kyoto Protocol is an international treaty designed to tackle climate change through the imposition of binding GHG emission reduction targets on developed countries, which means developed countries had to give a commitment that they would reduce their GHG by so much percentage. Despite playing a crucial role in global climate change, the protocol encountered challenges including the absence of binding commitments for developing nations and withdrawal of significant countries. So, many of the developing countries refused to give a commitment because their justification was that the developed country has already done the damage to the environment and developed themselves.

while the developing countries they are struggling to become developed why would we compromise on our development when the developed countries have already done the damage so they wanted a better or a more stringent commitment from the developed countries nevertheless Serving as a cornerstone for subsequent climate agreement, it still remains a contributor to ongoing international endeavors to combat climate change. However, it laid the foundation for subsequent climate negotiations and agreements and that is one major important contribution of the Kyoto Protocol which though it was a COP3, we still talk about it. The Paris Agreement which is COP21 is yet another important initiative. It was held in 2015 and the Paris Agreement forged to establish ambitious targets to combat climate change by capping global temperature increase at well below 2 degree Celsius above pre-industrial level, with a determined effort to limit it

to one and a half degree Celsius. Diverging from the Kyoto Protocol, this agreement is inclusive, encompassing all nations.

So, it is not about developed or developing, but all nations have to make a commitment and each country is tasked with formulating its own nationally determined contributions for mitigating greenhouse gas emissions with an expectation of continual enhancement over time. The Paris Agreement stands as a significant global initiative uniting nations in a collective pursuit to address climate change and construct a more sustainable future rather than have a divide of a developing and a developed country. Let's look at the Indian scenario very briefly. According to the World Resources Institute Climate Analysis, Indicator Tool, Now, India's 2014 GHG profile was dominated by emissions from the energy sector and it accounted for approximately 68% of the total emissions. Within this energy sector, 49% was due to electricity and heat generation, followed by 24% from manufacturing and construction.

So, India's GHG emissions in 2014 as per World Resources Institute Climate Analysis Indicator Tool, WRI-CATE, were predominantly driven by the energy sector constituting to a very high percentage of total emissions and you can see electricity was one very important contributor. Agriculture emerged as the second highest resource. So, we can see that energy especially from fossil fuel was a had a very high percentage of 68.7 and amongst this you can see manufacturing electricity and heat contributed so much and manufacturing and construction which is which is something of concern directly to architects and civil engineers had a major contribution amongst this emission.

Next to it is only agriculture which is less than 20 percent. So, about one third yes about one third is only agriculture. And then we will we are almost coming to the end of this looking at the Indian scenario. In the Indian scenario according to WRI energy emissions experienced a substantial increase of about 246 percent from 1990 to 2014. So, if you see from the year 1990 from this year to 2014 there has been a very steep rise. So, somewhere here There has been an increase of about 246% and coal accounted for 76% of electricity generation followed by others like hydroelectricity, natural gas, nuclear, wind, fuel oil and biofuels.

Despite being the third largest electricity producer globally, India's per capita electricity consumption remains amongst the lowest. So, in terms of absolute quantity, yes, India produces a lot of electricity and the impact of producing humongous amount of electricity reflects on the GHG emissions, but per capita consumption is still lowest. Industries consume largest share of about 42% followed by the residential sector which is 26%. Note the point, the residential sector consumes 26%, a key area where we as architects, civil engineers, building designers and planners have a large role. Agriculture and

forestry contributes 15%, commercial and public services 10% and others 8%.

So, in this class I will just summarize quickly what we have learnt is we have learnt that what is greenhouse gas, we have learnt the impact of GHG on the environment, why it is important for us to control GHG and you know the quantum contribution of GHG by the building sector.