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DAVID HSU: My name is David Hsu. I'm a professor at MIT in the Department of Urban Studies and Planning. I'd like to welcome you to another lecture in my series on Urban Energy Systems and Policy.

Today, we're going to talk about cities and industrial emissions. And what I want to do in this class, in this lecture, is connect cities to the larger issues of industrial emissions, partly because industrial emissions don't always seem to be very present in cities or don't seem to connect to cities as centers of consumption, as I've been talking to you about in this lecture series. But also, industrial emissions are a considered an extremely tough-to-decarbonize sector.

We have to replace the electricity, but also crucially the heat. And the materials we use in industrial systems to reduce our greenhouse gas emissions, that doesn't always seem to be an area or a scale at which cities can affect this kind of policy. But we'll explore today in this lecture how cities can affect or reduce their industrial emissions.

The materials for today are all in syllabus. If you have the PDFs, then please go ahead and you can link to these materials to read them before the lecture. The lecture will build on these materials.

And the themes I want to focus on today are consumption as a mechanism of greenhouse gas emissions. That's something I've said to you before in previous lectures. I want to emphasize consumption as a connection to larger energy systems. I think I've said to you also in previous lectures how we often focus on changing the energy system, how energy is produced, how it is transmitted, but not always thinking about how we can change how energy is consumed.

I'll also argue, too, in today's lecture that industrial emissions have very strong environmental justice implications. It also is perhaps connected to our urban-rural, regional, and political polarization over climate action. And then we'll finish today an in-class discussion, thinking about how we might transform this industrial system both within cities and from cities also.

And so if we just start with MacKay's calculation in chapter 15, he talks about lifecycle analysis. He talks about the energy or sustainable energy required to obtain raw materials, how do we produce finished goods out of the raw materials, how do we use those materials, acquiring energy. And ultimately, how do we dispose or get rid of materials by calling it waste? It's something we talked about in the last lecture on energy efficiency.

And the materials he goes through briefly in chapter 15 are the production of raw materials like aluminum or steel, packaging, chips, semiconductors, paper, building, construction, and roads, automaking. And of course, MacKay makes the point that a lot of things aren't necessarily made in the UK anymore. They're quite often imported. So that is embodied energy in the form of materials and goods being brought into the UK.

And surprisingly, if we look in his stats-- we haven't visited revisiting this concept for a while. If you look at all the previous chapters, we've talked about heating and cooling and jet flights and cars-- stuff and the transporting of stuff is the largest category so far. And so far, by chapter 15, he is tipping us over into more consumption than we can produce from sustainable energy resources on the right.

If we just think about some of these energy uses on the same footing, the stuff per person that MacKay calculates in Appendix H around is 41 kilowatt hours per day. That's 41 kilowatt hours per day as a rate of energy use. Hot water, hot air, and cooling add up to roughly about 37 kilowatt hours per day. And the construction of the house that MacKay estimates-- I think a typical English house, just the shell of the house itself is about 42,000 kilowatt hours over 100 years. The house is assumed to last 100 years.

So if you put that on equal footing, it's only 1.2 kilowatt hours per day. So we might conclude from these back-of-the-envelope numbers in MacKay's book that materials and construction aren't really a problem. Well, let's just question this for a second. There's obvious reasons why by putting things in the same footing, by amortizing this energy over 100 years, we might be missing some things.

First, the houses that we construct now in this calculation are assumed to last for 100 years. Not only does that assume we don't retrofit or modify them or redecorate them or demolish in the next 100 years, which is obviously an assumption that probably does not hold in many North American cities, let alone vast developing countries, but also, it assumes that the house construction that we do today is essentially baked in.

We're locking in that energy construction now. We're locking the energy implications of that house construction now. And we're actually omitting the carbon emissions of that now. So not only do we calculate this energy basis and average it over the next 100 years, but it matters much more if we actually do a lot of construction and emit a lot of carbon now-- much more today than 100 years from now.

As I've said to you multiple times this class, we have a mid-century goal of 2050. If we assume that we're going to stop doing any construction after this next 10 years, that might be one thing. But we've still frontloaded our energy or our carbon emissions today for the next 100 years. We can make this assumption. So perhaps averaging everything over 100 years is not the way we should think about it.

But another argument I want to make to you is that there's definitely different implications of industrial emissions for livelihood and climate action. In one of the previous lectures-- I think even the second lecture for this class, I talked to you about Robert Bullard. Robert Bullard is an environmental justice scholar-- really in some ways, the father of environmental justice. And as I said to you in the second lecture, he discovered early on in his career as a sociologist that 100% of the landfills in Houston were located in Black neighborhoods, though the Black population was only 25% of Houston's population.

At the same time, this paper we read by Sandeep Pai and others-- this is the same author. He recently wrote a book called *Total Transition.* And it's called *The Human Side of the Renewable Energy Revolution* because he focuses on workers in the fossil fuel industries, and argues that if we have a renewable energy revolution, it is going to disproportionately affect these workers.

So he investigates the situations of workers both in India and in Canada. And these two things are not unconnected. First, the environmental justice implications of fossil fuel use and consumption and production, focused on by Robert Bullard and Shalanda Baker-- if you remember that article we read maybe a few weeks back. But Sandeep Pai also says that in terms of justice implications, there's obviously a very large literature review focusing on a large literature looking at why this is going to affect workers and why workers might resist trying to take climate action.

A similar argument has been made by Matto Mildenberger in his book *Carbon Capture.* He argues that our coalitions for climate action are also, we have to recognize, split. Business and labor have influence on the left and right coalitions for or opposing climate action. So he argues that climate action in multiple countries has been stymied by the fact that even for coalitions that argue for climate action, business and labor have had substantial influence in stopping or exempting certain industries from climate action.

And so just to give you another sense of how cities are connected to industrial nations, quite often in this class, you're talking about cities that have relatively high population density and population. Looking at the population density and population in the United States, this vertical axis is the log of population density. The horizontal axis is the industrial greenhouse gas emissions as a percentage of the total greenhouse gas emissions for the county. This is all calculated from EPA'S industrial greenhouse gas figures. You can click on this link and see the numbers there, or calculate them yourself if you want.

But the point is for cities, if you look at the log of population density, you can see in the United States we have a nice bell curve. If you put a histogram on the side or a density plot on the side, the log of population density, it is relatively bell curve-shaped. You can see, that means if we take the population density, we have a few cities that are very high in population density like New York. And the vast majority of cities are lower population density, but I take the log because it makes the data clearer.

And so if you consider, for example, the highest population density and population counties in each state, Cook County is the seat of Chicago, Illinois. You can see how it's mostly low individual greenhouse gas emissions as a percentage of total. For the other highest population density and population counties in each state, that's true for Maricopa County, which is the home of Phoenix, Arizona, Dallas County, which is the seat of Dallas, Texas, King County, Washington, Seattle, as well with low industrial emissions.

Wayne County is the seat of Detroit. And New York County is one of the four very high population counties that comprise New York. And so generally, the way we talk about cities as centers of consumption, if these are the cities that come to mind, then yes, we have relatively low industrial emissions associated with cities.

But now let's look at this chart. If we look at this chart, we can see that there's all these other cities out here that have much higher industrial greenhouse gas emissions. Which cities are those? Which counties are those? If we look at the-- Philadelphia also has relatively low industrial emissions as a percentage of its total.

But if we look at the highest population density and relatively high industrial-emitting counties in each state, then we get to a different set of cities that we don't often talk about in urban planning. Tulsa, Oklahoma, Newcastle, Delaware have about a quarter of their greenhouse gas emissions are from industry. Denver, Colorado, has relatively high greenhouse gas emissions. Jefferson County in Alabama has relatively high greenhouse gas emissions.

Dallas, again, shows up on this list, and about 20% of its emissions are from greenhouse gas-- 20% of its greenhouse gas emissions of its total. So it's higher than other cities that we looked at. And Cuyahoga County in Ohio, the seat of Cleveland, also has surprisingly higher, but still relatively low, greenhouse gas emissions.

Let's look at some of the cities that have extremely high industrial emissions as a percentage of the total. What are those cities and counties? If we look at the highest industrial-emitting counties with high population densities, East Baton Rouge, Saint John the Baptist County, Calcasieu County-- mispronounced that, and St. Charles County and Ascension County are all in Louisiana. In fact, if we go back to Robert Bullard, the reason why he started studying environmental justice the first place, you can see that the highest population density and industrial-emitting counties are all in Louisiana, Texas, Virginia. These are not only places that are concentrated in a few states. Remarkably high proportions of their greenhouse gas emissions come from industry-- about 70%, up to 92%, in Covington, Virginia that have extremely high populations for their area.

They have very high population densities. But also, what I want to emphasize to you is that they have extremely high nonwhite populations that, in this case, not only are the people subject to the consequences or the burdens of industrial emissions. But these are all people who also may work in these industries as well. So this hopefully brings into focus the way that these different ideas about livelihood and environmental burden and climate action can coincide.

All of these counties are extremely high percentages of nonwhite population, in many cases African-Americans. They have high population densities. These are essentially highly urbanized areas, and they are areas that also have very high industrial emissions. This is an area in Louisiana, I guess, known recently as Cancer Alley. It's a phrase used in this ProPublica investigation about "Welcome to 'Cancer Alley,' Where Toxic Air Is About to Get Much Worse."

The article is about how air quality has improved for decades across the United states, but Louisiana's backsliding because their analysis found that many new industrial plants will increase the concentration of cancer-causing chemicals in predominantly Black and poor communities. So if we think about cities' industrial emissions, it's not only cities like New York that are perhaps centers of consumption. But other cities actually have high concentrations of industrial pollution within the city boundaries, or the county boundaries as well.

If we look at how fossil fuel infrastructure is distributed across the US, these are some graphics that my student Darryle Ulama and I made a few years ago from the US Energy Information Administration and Homeland Security data. You can see power plants are relatively distributed across the US. This graphic of coal, natural gas, and petroleum plants effectively follows the population or the urban pattern of the United States.

But you can see that natural gas is highly concentrated in the exact places we've just talked about-- Texas and Louisiana prefer. Virginia is a different case, I think, out there. If we look at natural gas, it's highly concentrated here, partly because import and export, but also because of petrochemical refining and production. And if we look at only oil and petroleum, you can see our pipelines again run from Texas, Louisiana, pretty much following the urban patterns of the United States. We look at cumulative impacts, yes, we see fossil fuel infrastructure concentrated across the United States.

But clearly, based on the industrial emissions we looked at before, the industrial emissions are very differently distributed across urban areas the United States, which brings me to the Ahman et al, 2017, paper. Just to focus on this paper, it's about global climate policies for energy-intensive industries. We're going to go through a bunch of acronyms here. At the global level, we have energy-intensive industries like steel, cement, aluminum, fertilizer, and plastics. That's EII.

BATs are the best-available technologies. But crucially, the paper argues that they only reduce emissions 15% or 30% So hopefully, in the five years since this paper was written, we've come up with more ideas for how to decarbonize industry. But at least the best available technologies five years ago only reduced emissions a fraction of what we need.

There's a number of other acronyms quite often about international climate negotiations-- common-but-differentiated responsibilities, CBDRs. Clean development mechanism, CDM-- this is a mechanism intended for rich countries to help poor countries decarbonize and meet their INDCs, their intended nationally-determined contributions.

This is what we said in the Paris Climate Agreement. Every country came, said what their intended nationally-determined contribution was of the INDC. Basically, every country came and said this is the best we could do on climate change.

Of course, there's a lot of discussion now in climate policy about border carbon adjustments. These are the border carbon adjustments that rich countries might use to try to account for the embodied energy that they're importing, but also that's hopefully not causing additional leakage of jobs to other countries.

In other words, if other countries seem like they have low greenhouse gas consumption or emissions associated with consumption, and maybe because they're actually exporting their goods to rich countries. So both rich and poor countries have proposed border carbon adjustments, where we can hopefully account for this at the border when materials and goods are imported. And finally, CCS is something we're going to talk about a lot going forward. Carbon capture and storage, often called carbon capture, utilization, and storage now.

Just to give you a sense of where greenhouse gas emissions have gone, this is a plot from the Ahman paper. If the data is normalized in 1990, when the UN started accounting, you could see that world emissions have gone up. Emissions in Japan and the EU have gone down.

In the US, they've stayed relatively flat, either industrial, direct greenhouse gas emissions. But obviously, rapidly developing countries like China, India, and Brazil have rapidly increased their greenhouse gas emissions. But we should also recognize that these greenhouse gas emissions have increased in these countries because of their exports to the rich and developed world.

And so this brings up fundamental issues of efficiency, equity, and fairness. There's a lot of issues that need to be negotiated within and between countries around industrial emissions. There's the idea of carbon leakage. This is where there will be a loss of competitiveness and relocation of industry to other countries.

There's questions about political stability, transportation infrastructure, labor legislation and protections, access to markets and feedstock, and industrial policy. The reason why we're talking about it in this urban planning class is that we think about all these as issues to be negotiated within and between countries. The key issue for cities is how do we negotiate these issues between cities and within countries?

In other words, again, if we have centers of consumption, quite often on the coasts, we are drawing on industrial emissions that are in other parts of the country or other parts of the world. How do we account for this consumption? What do relatively rich developed areas, such as cities in North America, have to do to account for their emissions or how to make up for their consumption?

So this again is a good time to focus on how we can scale down some of these national policies. And I'll argue to you that a lot of these policies that exist at the national level that are discussed in this Ahman paper also have equivalents at the urban scale. For example, in the first policy here, we have mitigation policies and measures that have an intended, direct effect. We have mitigation policies and measures with intended long-term effects.

In the EU, we had a regulated target for industry together with the power sector to reduce its greenhouse gas emissions via the emissions trading scheme. We've obviously discussed possible emissions trading schemes in the US. Not only does California have an emissions trading scheme within California. We have the Regional Greenhouse Gas Initiative, RGGI, on the East Coast, trying to trade emissions within the East Coast or mid-Atlantic states.

We also have the Clean Power Plan, which would allow the power sector in different states to meet emissions targets in different ways. Regulations reducing emissions of industrial gases-- I think some states have increased, like RGGI in California, having these regulations designed to reduce emissions of industrial gases. And there's energy efficiency directives that can be applied differently at the city and state level. We also have, in our most recent legislation, the Inflation Reduction Act. We have funding for demonstration of carbon capture and storage and bioenergy for sure.

Japan has implementation of voluntary action plans by industries for promoting energy efficiency. Obviously, in the last few classes, we've talked about how cities have implemented different energy efficiency programs. We also have subsidies for increasing the adoption of best-available technologies.

We have a low carbon technology roadmap relevant to steel. I think we have that in our new Inflation Reduction Act legislation. We definitely have roadmaps for low carbon production of industrial production.

And finally, the ENERGY STAR program for industry for adopting energy-efficient technologies, this is purely a US-level policy. But as I spoke to you about benchmarking, benchmarking is essentially built on ENERGY STAR. We have benchmarking programs to encourage adoption of energy efficient technologies in buildings and so on.

Now, the interesting part for cities and industrial emissions is the policies that exist in developing countries arguably could be applied to cities that are producing a lot of industrial emission-- like we talked about, Louisiana, Texas, and Virginia, and other parts of the country. We have major programs on energy efficiency in industry. In China, we have mandated phase-out of outdated backward industries. We have pricing policies that favor energy efficiency.

And we have major clean development mechanisms to help China basically phase out non-CO_2 gases. We have other schemes in India and Brazil, such as sectoral plans for industry, including energy conservation programs. These are all things that can and are being applied to industrial emissions in cities that have more higher industrial emissions.

This brings me to the Rissman paper-- this Rissman paper with many co-authors. We're going to use this as the basis for our discussion in class. And what I want to emphasize to you, just maybe a few points in the paper before we go into the discussion together, this is a figure showing emissions by sector.

The left-hand side has the groupings by sector, including, let's say for buildings, indirect and direct energy-related emissions is 24% of heat, and electricity emissions is aggregated. If we group heat, electricity, and heat emissions together, buildings only seem to be about 8%. But this is a considerable divergence from where we started the lecture from. In other words, buildings consume a very large portion of energy in this aggregated view of both heat and electricity emissions. If we group it together, then we hide some of the building emissions in the power sector.

But if we look specifically at how much energy or how much emissions are associated with different sectors by industry, you can see the number two or three are iron, steel, chemicals, and plastics and cement. Aluminum, refining, machinery, pulp and paper-- all of these various manufacturing or production activities result in high greenhouse gas emissions. These are a significant fraction of the world's greenhouse gas emissions we've been talking about.

So what we'll talk about in our class discussion are various policies and interventions. On the supply side, some of the ones that students were interested in last year were carbon capture utilization storage, low carbon development for developing countries. How could we apply that to cities? Worker retraining programs, firms influencing government decisions, low-carbon steel production, electrolysis, renewable energy production, electrification, hydrogen production and use.

On the demand side, students discussed [INAUDIBLE] material substitution, material efficiency, reduced material use, sharing of public goods, efficiency standards, the circular economy, data transparency, and of course building codes. Thank you very much. I look forward to our discussion in class in person.