Researchers create new tool to analyze embodied carbon in more than 1 million buildings in Chicago

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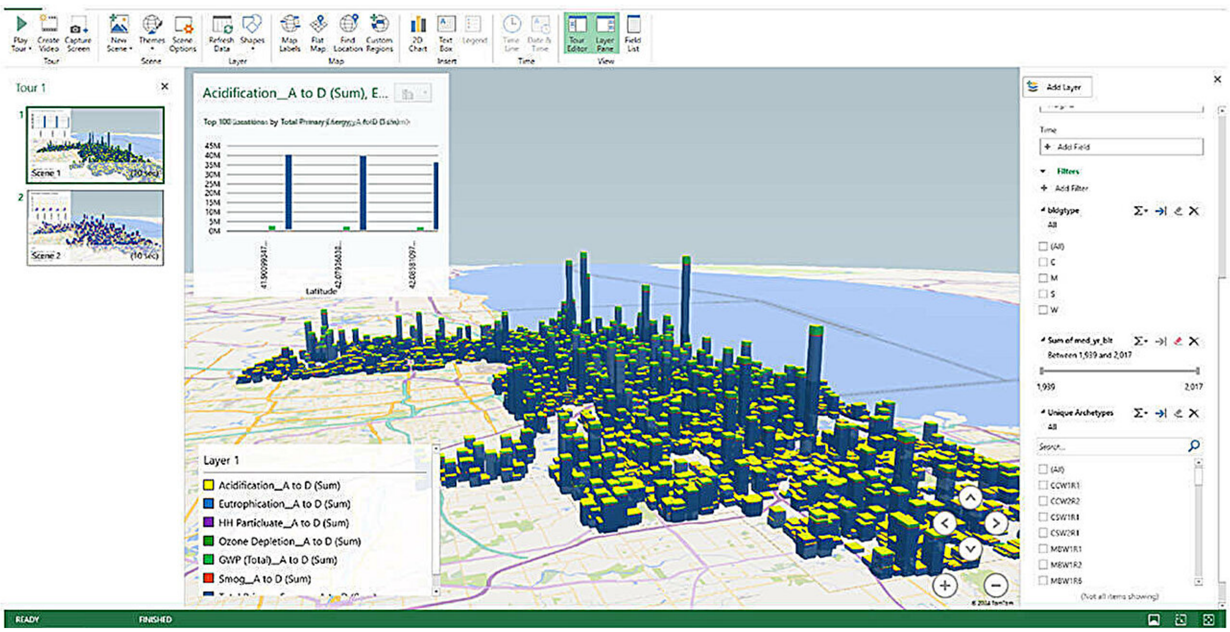

Ming Hu, associate dean for research, scholarship and creative work in Notre Dame's School of Architecture, and graduate student Siavash Ghorbany created the first ever visual analysis tool to evaluate embodied carbon in more than 1 million buildings in Chicago. Credit: University of Notre Dame

The built environment—which includes the construction and operation of buildings, highways, bridges and other infrastructure—is responsible for close to 40% of the global greenhouse gas emissions contributing to climate change.

While many building codes and benchmarks have focused on constructing "greener," more energy-efficient new buildings, it is not enough to seek to reduce emissions in operations, said Ming Hu, the associate dean for research, scholarship and creative work in Notre Dame's School of Architecture. Rather, policymakers and industry leaders must take a broader view by examining the role of embodied carbon in existing buildings.

Embodied carbon represents the amount of greenhouse gas emissions associated with the entire life cycle of a product, including the extraction, production and transfer of materials; the manufacture of the product or building; and its eventual disposal or demolition. In the construction field, materials such as asphalt, concrete and steel, in particular, have dire consequences for the environment.

The impact of embodied carbon in the built environment has been difficult to assess, however, due to a lack of data. To address that knowledge gap, Hu and Siavash Ghorbany, a Notre Dame graduate student in civil and environmental engineering, have created a new way to analyze the embodied carbon in more than 1 million buildings in Chicago.

Their research, recently published in *Carbon Management*, identifies 157 different architectural archetypes in the city and provides the first ever visual analysis tool to evaluate embodied carbon at a granular level and to help inform policymakers seeking to strategically plan for urban carbon mitigation.

"Before, it was often difficult to visualize this concept and to make a case for why we want to preserve and reuse existing buildings," Hu said. "We feel this is a more clear, direct way to help the policymaker or layperson make informed decisions.

"If I were the mayor of Chicago, I could look at this and say, 'OK, before I tear down this building, I have to think twice because there's already a lot of carbon embedded in this structure. Do I want to retrofit and reuse this building, or do I want to knock it down and build new, which will increase the overall embodied carbon?'"

Hu and Ghorbany were able to identify emissions-intensive geographic zones and specific archetypes within the city—delivering actionable data to urban development stakeholders. They also found that increasing the average lifespan of buildings from the current 50 years to 75 years, and reducing their size by just 20%, can decrease their carbon emissions by two-thirds.

Hu emphasized that her research has found no scenario where tearing down an existing building to build something new—even if that new building is more energy efficient—makes sense, from an environmental perspective.

"If we look at the building's entire lifespan, renovating the existing building has significantly lower carbon emissions over its whole life cycle, including operational and embodied carbon," said Hu, who is also an affiliated faculty member in the College of Engineering.

"That's because the 'payback period' for constructing a new building is typically 20 years due to the high level of greenhouse gas emissions created by its construction. So, if we can extend a building's life cycle to 70 or 80 years, then reusing the existing building definitely makes more sense.

"We should always reuse existing buildings. The real question is just to what extent we want to renovate and retrofit them."

Hu and Ghorbany selected Chicago for a number of reasons, including its close proximity to Notre Dame, its architectural history—and because the city is ranked as the 8th highest for greenhouse gas emissions in the world. Going forward, they plan to scale up the project to evaluate embodied carbon in cities across the U.S.

The researchers used machine learning and artificial intelligence to create an integrated dataset for their analysis, pulling from a variety of existing datasets, including the National Structure Inventory and Cook County Open Data for Chicago.

They matched the different types of data using their geolocation, then coded and categorized them based on different features, such as structural materials and roof type. From there, they multiplied the archetype's baseline emissions by the footprint of each building to approximate its total embodied carbon.

Ghorbany, who is also a Graduate Scholar in the Lucy Family Institute for Data & Society and has an undergraduate degree in architecture, said that creating an accessible, interactive mapping tool to help visualize their findings was a top priority.

"Our goal for the end product was to create a user-friendly way to access and engage with this data," he said. "We created this one so that you can try different scenarios by selecting which types of archetypes you want to see and filtering them by year or types of emissions. I hope that in the future, cities will be able to use this tool to reduce their carbon emissions so that we can help reduce climate change and the impacts we're seeing from it."

Hu agreed, and noted that the potential benefits of this research are not only environmental, but also cultural.

"First, it is crucial that we have a clear inventory of the embodied carbon in our built environment," she said. "It's something we've never had before and still don't have nationwide. Once we have that, we can make informed decisions about how to reduce our carbon emissions, in part, by extending the lifespan of these buildings.

"And, in addition to the environmental benefits, there is social and cultural value to preserving these buildings that are part of the architectural character of the city."

More information: Siavash Ghorbany et al, Urban embodied carbon assessment: methodology and insights from analyzing over a million buildings in Chicago, *Carbon Management* (2024). DOI: 10.1080/17583004.2024.2382993

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