Podcast Interview: Hessam AzariJafari, Randy Kirchain, and Jeremy Gregory

PNAS: Welcome to *Science Sessions*, the podcast of the *Proceedings of the National Academy of Sciences*, where we connect you with Academy members, researchers, and policymakers. Join us as we explore the stories behind the science. I'm Paul Gabrielsen. Concrete is found everywhere in our built environment. It's a versatile and widespread material, but is a significant source of greenhouse gas emissions. I'm speaking with Hessam AzariJafari of the University of Michigan and Jeremy Gregory and Randy Kirchain of the Massachusetts Institute of Technology. In a recent PNAS article, they and their colleagues modeled the emissions associated with the life cycle of concrete, including its production, installation, use, and disposal, over the next three decades. The model included an ambitious scenario that included significant measures to reduce greenhouse gas emissions. The results showed that building better concrete can improve the emissions of cars and buildings such that overall emissions can decrease even as concrete use increases.

Hessam, why is concrete production a significant source of greenhouse gas emissions?

AzariJafari: So in order for us to produce Portland cement for making concrete, we need to use a substantial amount of heat and we need to heat the raw materials. And this combustion process will emit a lot of CO_2. The other part of the CO_2 associated with the Portland cement production is called process emissions, and it's about the decomposition of the materials, more specifically limestone, that will generate some CO_2 as well.

PNAS: Randy, what is the scale of the emissions associated with concrete production?

Kirchain: It's interesting that the unit impacts of concrete are not particularly high when you compare it to other construction or infrastructure related materials, but the scale of the industry is such that it does generate somewhere in the 1 to 2% of greenhouse gas emissions for the United States.

PNAS: What is a life cycle analysis, and why is it useful? What are the life cycle phases relevant to this study?

AzariJafari: So life cycle assessment is a holistic tool that will help us quantify the environmental impacts of any products or service throughout its life cycle. And this tool will quantify the environmental impacts from the extraction of raw materials, production stage, the construction—for example, for our infrastructure or big buildings—the use or operational phase related to the energy required to run that business or products, and also the end of life where the materials will be disposed or recycled. And this holistic tool will give us a bigger picture and a better resolution for assessing whether a product or service is environmentally friendly or not.

Kirchain: It's often easy to think that the footprint, the impact, if you will, of materials comes about simply because of the emissions that come out of the smoke stacks at the plants at which those materials are created. But materials change the way that products behave, both in their use and at their end of life. And so if lifecycle assessment's the only way that we have to get that full picture of how a material choice not just changes that smokestack, but changes performance in use and later on. So it's a critical tool, I think. It's really the only tool for understanding the complete environmental impact associated with material choice.

PNAS: Jeremy, your model included projected and ambitious scenarios for greenhouse gas emission reduction in the concrete industry. What emissions reduction actions are included in each scenario?

Gregory: So in order to understand the potential for concrete to contribute to greenhouse gas emission reductions in the buildings and pavement sector, we defined a couple of different scenarios. One was a set of projected strategies, meaning that if innovations in the concrete sector continued as they have in the recent past, then we would expect those projected changes to continue through the year 2050. The other one is more ambitious actions that could be taken that would go beyond what we project. So this would lead to more significant de-carbonization of those sectors, but would also likely require either more changes to the systems or more investments.

A[n] example of a more ambitious strategy is actually to use captured carbon in the curing process of concrete. And so there are technologies that already exist to do that, but they're not very widespread, or they're not really reaching the full potential that they could. In the pavement sector, projected improvements are mostly tied to how much investment that we have in the pavement sector. A more ambitious scenario [is one] with significantly increasing investment in our maintenance and rehabilitation of our roads. And the reason that matters is that the condition of the roads affects the fuel consumption of the vehicles that drive on them. So more investment to create stiffer and smoother pavements leads to lower greenhouse gas emissions.

PNAS: What did the model show as potential emissions reductions in the building and pavement sectors by 2050?

AzariJafari: Yeah, I'm going to talk a little bit about pavements at first. So based on the results that we got from the ambitious scenario, we found that attaining the Paris Agreement pledge is feasible using these pavements and these ambitious actions on the pavements, while relying on the projected scenarios may lead us to have a long way to achieve the Paris Agreement pledge. So the other important observation that we have here is using specific types of materials with elevated properties would definitely help us save some operational impacts throughout the service life of our pavement systems and the embodied impact reduction also plays an important role in the GHG mitigation solutions and achieving [the] Paris Agreement pledge. Embodied impacts are those emissions associated with the production and construction of our infrastructure systems or buildings.

Gregory: In the building sector, the greenhouse gas reductions projected are actually pretty significant, and that's because we have a history in many states of energy codes that lead to energy reductions in new construction. And so we project those to increase across many states. Having said that, we still need the ambitious reductions in order to meet greenhouse gas reduction targets.

And in fact, we showed that they even fell a little bit short of our Paris Agreement targets, but I want to contrast that with the pavement sector where there's a significant difference between the projected and the ambitious scenarios, and a big reason for that is because in this country we don't adequately invest in the maintenance and rehabilitation of our pavement infrastructure. And as a consequence, most people don't have this connection to, then, greenhouse gas emissions of the vehicles that are driving on the pavements. So if we were to do the more ambitious scenario, a lot of it involves just doing more pavement maintenance and rehabilitation. But it's going to require a much bigger change than we saw with the building sector because the building sector is predominantly private, whereas the pavement sector is predominantly public. And so we need to think about our investment mechanisms differently in the building sector than in the pavement sector.

PNAS: Your article mentions that emissions reductions in the ambitious scenario occur even though concrete use is three times higher in that scenario. Why is that?

Kirchain: Yeah, that's made possible because of how the properties of concrete change the use phase impacts of those systems. So it allows the vehicles that drive over the roads to use less fuel. It's lighter color, rejects more energy back into the atmosphere, and it creates efficient and resilient structures. And so combined, those effects lead to benefits that are far beyond those of the additional embodied emissions that are associated with the production of it.

PNAS: What are some of the most impactful actions that governments or industry can take to reduce concrete-related emissions?

Kirchain: One is continued support for the development of carbon capture, to lower the cost and ease the implementation of that, is an important public investment. I think investing in a better quality, stiffer road system is an important investment that we can make that generates significant greenhouse gas emissions benefits.

AzariJafari: Currently, especially in the public sector, we don't have that comprehensive life cycle thinking mindset when we are making the decisions for our pavement systems, for example. In other words, the user cost or the operational impacts of pavements are usually neglected in the decision-making. And most of the focus is on the materials, environmental impacts, and also costs.

Kirchain: This study is a life cycle assessment and as such, it intends to capture all of the relevant effects. There are many benefits that come about from building better buildings and building better roads. When our results show that there is a decrease in emissions, that is net of any increase in emissions that comes about from production. There are emissions from production. Those will go down over time. And our benefit comes about not only from those decreases, but also benefits in the use phase that offset any of those.

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