New tool finds the best opportunities to reduce, reuse and recycle across industrial sectors

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A new tool finds hidden connections across industrial sectors and identifies opportunities to reduce waste and lower carbon emissions by mapping the physical economy for a region.

"The climate and the economy are too important for us to make mistakes," said Shweta Singh, the interdisciplinary scientist at Purdue University who developed the tool. "This tool provides a big-picture view and allows policymakers and industry to plug in a potential change and see the results. Those involved can virtually test different options before making a decision."

Past zero-waste and low-carbon efforts focused on one portion of industrial flow, for example, reducing energy use in a single production process. However, a view of the whole system is needed to make the best choices and most effective investments in emerging technology for overall improvement, she said.

"The approach is like the human genome project, but for the physical economy—mapping the relationship between industry and the environment," said Singh, who holds appointments as an assistant professor of agricultural and biological engineering in the College of Agriculture and environmental and ecological engineering in the College of Engineering. "It allows us to find and understand connections within the whole system. We needed the human genome project—the complete map—to begin to identify the genes key to disease or health, and we need a complete map of the physical economy to identify what changes are key to achieving sustainability."

The theory behind the model is detailed in a paper in the journal *Energy & Environmental Science* of The Royal Society of Chemistry. A paper focused on the cloud platform tool will be published in the *Journal of Industrial Ecology*.

The tool uses physical principles and mechanistic models from physics, engineering and biological sciences to automate mapping of the physical economy, and it is much faster than the standard methods, Singh said.

"With this modeling tool, we can do in one day what would have taken 100 days," she said. "The existing mapping methods were tedious and time-consuming. By looking at each economic sector as a process—taking resources through physical changes to create a product—we can use existing mechanistic models to map a multiscale view of the physical economy. With that in place we can make changes and see the cascade of events from the process to sector to whole economy."

Singh used the tool to map the physical economy of Illinois for 10 agro-based sectors from farming to downstream processing of products. The model found connections and highlighted opportunities for large-scale recycling to reduce waste. The results showed that the adoption of technologies for industrial wastewater and hog manure recycling would have the highest impact by reducing more than 62% of hog waste outputs, 96% of dry corn milling waste, and 99% of soybean hull waste.

"We also found indirect connections, for example recycling hog farm waste led to reduced emissions down the line in manufacturing," Singh said. "In the supply chain, experts talk about first, second- and third-order impacts. Third-order impacts may not be obvious, but they can really have an impact. Here it becomes transparent, and we can identify that third-order impact very quickly."

Singh credits a diverse academic background in sparking the idea for the model.

"I always had an interest in various disciplines," she said. "My friends joked I had taken a class in every building on campus. I actually began my studies in chemical engineering, which takes a very close look at the flow of a chemical reaction and the byproducts created. Then, while studying sustainability assessment for industrial systems, I broadened my scope to macroeconomic framework. It led me to wonder why there wasn't more communication and crossover between the disciplines. In this model, I try to bring all of these things together, connecting process engineering with economic modeling."

Singh also credits the interdisciplinary background of Venkata Sai Gargeya Vunnava, the graduate student who collaborated on the project.

"Thinking about the challenge without being mentally stuck in a single academic discipline led to this innovation," Singh said. "We must be open to learning anything from anywhere."

Singh disclosed the modeling tool to the Purdue Research Foundation Office of Technology Commercialization, which has applied for patent protection on the intellectual property.

More information: Venkata Sai Gargeya Vunnava et al, Integrated mechanistic engineering models and macroeconomic input–output approach to model physical economy for evaluating the impact of transition to a circular economy, *Energy & Environmental Science* (2021). DOI: 10.1039/D1EE00544H

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