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Turning Emissions into Plastics

With global emissions continuing unabated, climate change is proceeding at a startling pace. But a team of scientists from UC Santa Barbara and RWTH Aachen University in Germany have a new — and novel — destination in mind for all the carbon dioxide spewing into the atmosphere: chemical products.

Chemical production emits staggering amounts of greenhouse gasses via the energy it consumes and the carbon-based raw materials it uses. Sangwon Suh, a professor in UC Santa Barbara's Bren School of Environmental Science & Management, and his fellow researchers see an opportunity to divert billions of tons of CO_2 from smokestacks into the chemical supply chain, if the world can create enough renewable energy to make the effort worthwhile. Their analysis appears in the Proceedings of the National Academy of Sciences.

According to the team's findings, chemical production — an industry encompassing sectors as diverse as lubricants, paints and plastics — accounts for over 3.3 billion metric tons of CO_2 per year, or the equivalent in other greenhouse gasses. Suh recently released the first comprehensive account of carbon emissions from plastics, in which he and his coauthor discovered that plastics alone account for the equivalent of 1.8 billion metric tons of CO_2 emissions per year.

"On the one hand, this massive quantity of plastic and chemicals poses a problem," said Suh, who researches industrial ecology, "because a huge amount of energy is needed in production and, once the products are used, a huge amount of waste will be generated."

“On the other hand,” he continued, “this is an opportunity, because these raw materials are largely carbon-based. If we can use carbon dioxide as a carbon source for these plastics and chemicals, then we can capture and store a large quantity of CO_2 in the plastics and chemicals that otherwise would have been emitted, all while creating value.”

Applying carbon capture and utilization (CCU) to the chemical industry is a novel idea. It would provide a renewable source of carbon compounds and has the added benefit of pulling CO_2 out of the atmosphere. CCU also produces a large quantity of pure water as a byproduct, a potential boon as water security becomes a greater issue. What’s more, putting captured carbon to use offsets some of the costs of capturing it in the first place, a major economic challenge to carbon sequestration efforts.

But the team wanted to know how practical it might be. This is new territory, so the researchers mostly had to work from scratch. They set about testing whether CCU provided a sizable opportunity to reduce greenhouse gas emissions, and found that it did. The technique could eliminate up to 3.5 billion metric tons of CO_2, or the equivalent in other greenhouse gasses per year.

However, this process would increase the industry’s total energy demands mainly because it also needs hydrogen, which can be produced from water through electrolysis. These demands would need to be met with renewable energy, otherwise the process would emit more carbon than simply sourcing material traditionally, via fossil fuel reserves.

The question then became: how much renewable electricity is needed to reach this 3.5 gigaton technical potential?

The answer: 126 to 222% of the world’s current 2030 renewable energy targets. And these targets already look very ambitious under current policies and trajectories.

“We were surprised at how much electricity is necessary in order to reduce greenhouse gas emissions through CCU,” Suh remarked. “Some people may think that those renewable energy generation numbers that we tested are unrealistic. Well, that’s the point.”

Time and effort

Many scientists became interested in CCU — as well as carbon capture and storage — as they grew more worried that various proposals and strategies for decreasing greenhouse gas emissions may come up short. LED lights and electric cars produce less greenhouse gasses, but avoiding climate catastrophe requires more than just reducing emissions, Suh said.

“Scientists are starting to sense that these efforts will not be able to keep us to a 1.5 to 2 degrees Celsius global average temperature increase,” he said. These are the targets set by the United Nations following the report by the Intergovernmental Panel on Climate Change (IPCC) in order to prevent climate disaster. Keeping within these targets requires reducing net emissions to zero by the second half of the century, said Suh, who served as a coordinating lead author on part of the panel’s 2014 report.

This leads to the concept of a carbon budget, namely a maximum total amount of greenhouse gasses humans can emit and still keep warming below 2 degrees Celsius. Scientists have produced many estimates of this budget, but one of the most influential yields a figure of 763 billion metric tons of CO_2, or the equivalent in other gasses. Right now, we emit around 50 billion tons of CO_2 per year, Suh said. That doesn’t allow much leeway to work with, or much time in which to solve the problem.

“We have to dramatically reduce our greenhouse gas emissions immediately,” Suh said.

However, he believes that holding too rosy a view of the potential of carbon capture is dangerous as well. “Our study represents the first global assessment of the potential that CCU holds for carbon mitigation, and we found that it takes a lot for CCU to save the world,” Suh said. Humans can’t continue business as usual under the assumption that carbon capture to fix the problem even if we miss our targets.

“More than anything else, this study shows the enormous magnitude of renewable energy needed in order for CCU to make sense,” said Suh. He suspects those who read the study will balk at the requirements, saying that we cannot direct all that renewable electricity solely to CCU.

“I agree,” he said. “That’s the point.”

Best bang for your buck

If we did add the enormous amount of renewable electricity detailed in the study, it begs the question whether CCU is the best application of this additional power. So the team compared CCU with alternatives that may prove more efficient.

It turns out that CCU is not currently the most efficient use of renewable electricity for carbon mitigation. Investing this energy into heat pumps — rather than relying on natural gas for heating — would provide the biggest reduction in emissions per kilowatt-hour, followed by things like the electrification of transportation and water heaters. Only after all these other, more efficient uses of renewable electricity are exhausted would it then make sense to invest green energy into carbon capture and utilization.

However, if extra capacity is generated, CCU could prove a valuable tool in reducing greenhouse emissions, according to the scientists. The sheer tonnage of carbon-based compounds that flow through the chemical industry gives CCU the potential to have an outsized effect on curbing emissions.

“We didn’t find CCU as a savior of the global environment,” Suh said, “although it might have some local potential, where there is an excess supply of renewable electricity with no apparent uses.”

In that case, however, the bulky plastics and chemicals produced would need to be shipped to market, thereby generating more emissions. Instead, the excess electricity could go toward processing data, which is much more efficient to transmit around the globe, Suh said. He and his colleagues are now examining the role data centers and outsourced computing could have on reducing emissions by making the most efficient use of available energy sources.

About UC Santa Barbara

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