Sustainable fertilizer production method proven to be cost-effective

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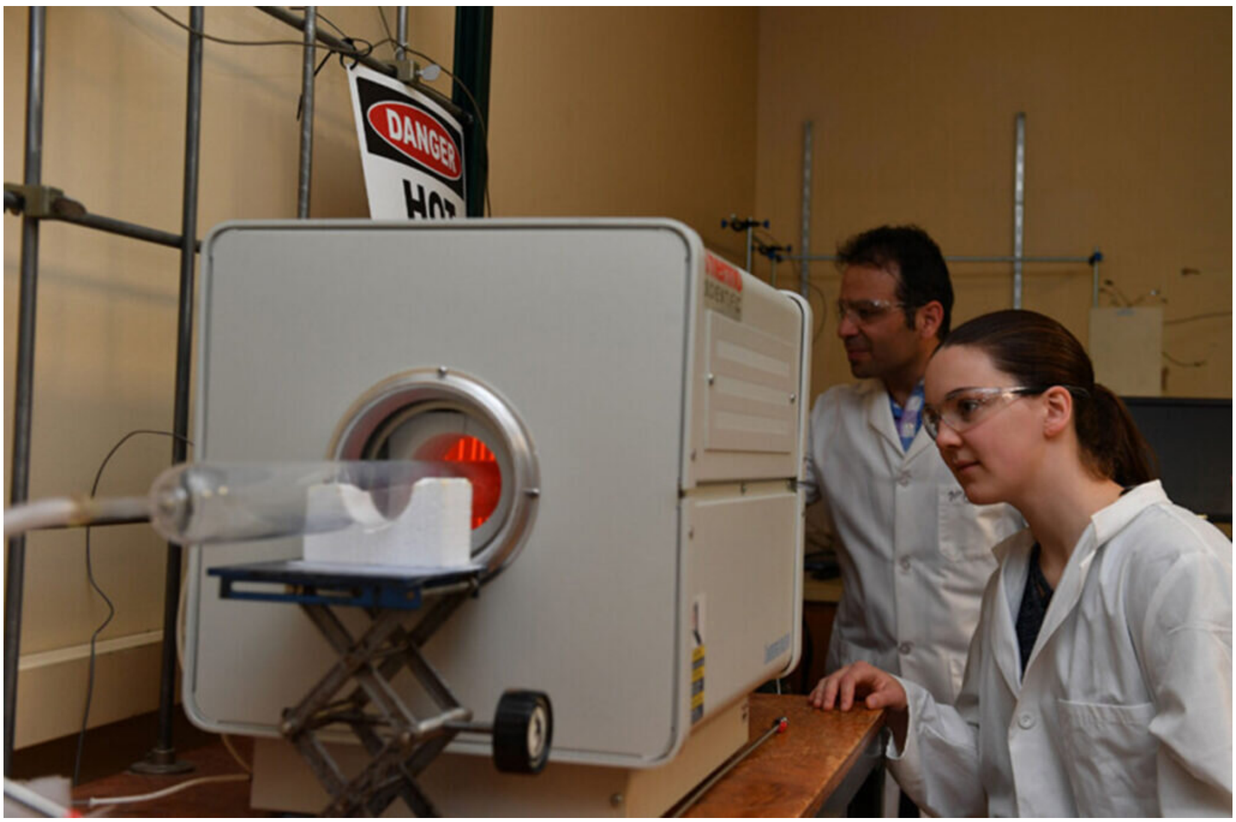

Chemical Engineering PhD Candidate Wrya Aframehr and undergraduate student Constance Kirby work with a high temperature reactor to produce ammonia via chemical looping of manganese. Credit: Washington State University

Sustainable methods to produce synthetic ammonia for fertilizer can be cost competitive with the current fossil-fuel based method, according to a Washington State University study. The findings indicate that these methods are plausible commercial options that can reduce carbon emissions and help increase market stability in an industry that is critical to food production.

In a study published in the *Journal of Renewable and Sustainable Energy*, researchers in the Voiland College of Engineering and Architecture found that the cost of ammonia sustainably produced using steam or water electrolysis was comparable to the currently used method of producing ammonia that uses either natural gas or coal. The study shows that sustainable fertilizer production might be economically attractive, particularly for small-scale operations.

Synthetic ammonia is critically important for feeding the world's growing population. Approximately 180 million metric tons of artificial fertilizer provides about 40% of the world's food each year, and all of it is made from fossil fuels. Producing ammonia releases about 2–3% of global fossil fuel-based carbon dioxide emissions into the atmosphere.

"It's an irreplaceable product and probably the most important achievement of the 20th century," says Peter Pfromm, lead author on the paper and a professor in the Gene and Linda Voiland School of Chemical Engineering and Bioengineering. "But right now you and I, to a large part, are fossil-fuel based life forms, and that's not really sustainable."

The fossil-fuel process used now, called the Haber-Bosch process, is more than a century old. With high temperatures and extremely high pressure, the process pulls nitrogen from the air and converts it with hydrogen to produce ammonia. Because the process requires using natural gas or coal, farmers who need fertilizer are completely dependent on fluctuations in those markets. For instance, this spring the price of fertilizer shot up from about $400 to $1500 dollars a ton, and because of the high energy costs, some fertilizer plants in Great Britain were closed.

"One of the worst things you can do to agriculture is have unpredictability," Pfromm said. "If you had local control of fertilizer production, you might be more resilient. Farmers would be so happy to de-risk their operation and have a predictable, reasonable price."

In their study, the researchers compared the energy cost of the Haber-Bosch process, which is based on conventional hydrogen production from natural gas, to two types of electrolysis. Electrolysis can use electricity created from renewable sources such as wind or solar power to split water into hydrogen, which is the most energy intensive part of ammonia production, and oxygen.

In solid oxide electrolysis (SOE), which is an emerging technology, very hot steam is contacted with a membrane where it splits into oxygen and hydrogen. The oxygen is removed selectively through the membrane, and pure hydrogen is left behind for ammonia synthesis.

In addition to hydrogen production, the SOE technology can also simultaneously separate oxygen from air, leaving behind the nitrogen needed for ammonia synthesis, and allowing for a simplified, renewable ammonia production process. Researchers are still working to develop the technology for the marketplace.

In the study, the WSU researchers found comparable energy costs for the fossil-fuel based technology, SOE, and water-based electrolysis ranging from $153 to $197 per ton of ammonia.

"There's a lab research angle to make it more amenable to downscaling, but there's also a techno-economic angle to this—to make sure one knows what the cost will be if we go to renewable energy," Pfromm said.

"We have to have a cost for the product that is competitive with existing natural gas-based mega plants that are running in the US and elsewhere. If the cost of energy per ton of ammonia is too high, then we don't need to worry about building it. This work shows that new solid oxide electrolysis, which is just scaling up, can compete with conventional fossil fuel-based ammonia synthesis."

In addition to the cost, the simple process and modularity of the renewable-based electrolysis might make it appealing for local-level ammonia production. Pfromm anticipates that small-scale, renewable ammonia production could begin happening at the county level or on large farms by as soon as 2024.

"If you do small-scale production on a farm or on a county level, we already know how to produce ammonia, how to store it, how to transport it, and we know how to permit all of that, because ammonia is already being used widely as fertilizer," he said. "Every farmer has experience with fertilizer."

More information: Peter H. Pfromm et al, Green ammonia from air, water, and renewable electricity: Energy costs using natural gas reforming, solid oxide electrolysis, liquid water electrolysis, chemical looping, or a Haber–Bosch loop, *Journal of Renewable and Sustainable Energy* (2022). DOI: 10.1063/5.0101709

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