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Demonstrating a CO₂ Recycler

Sandia scientists successfully test a machine that creates fuel from carbon dioxide.

By Tyler Hamilton

Researchers at Sandia National Laboratories have successfully demonstrated a prototype machine that uses the sun's energy to convert water and carbon dioxide into the molecular building blocks that make up transportation fuels. The "[Sunshine to Petrol](#)" system could ultimately prove a practical way to recycle CO₂ from power and industrial plants into gasoline, diesel, and jet fuel, assuming the process can become at least twice as efficient as natural photosynthesis.

Until recently, the system had only been validated in a laboratory in small batches. A hand-built demonstration machine was successfully tested this fall. "This is a first-of-its-kind prototype we're evaluating," says Sandia researcher Rich Diver, inventor of the device.

"In the short term we see this as an alternative to sequestration," says James Miller, a chemical engineer with [Sandia's advanced materials laboratory](#). Instead of just pumping CO₂ underground for permanent storage, Miller says, the sun's abundant energy can be used to achieve "reverse combustion" that essentially turns carbon dioxide back into a fuel. "It's a productive utilization of CO₂ that you might capture from a coal plant, a brewery, and similar concentrated sources."

The cylindrical metal machine, called the Counter-Rotating-Ring Receiver Reactor Recuperator (CR5), relies on concentrated solar heat to trigger a thermo-chemical reaction in an iron-rich composite material. The material is designed to give up an oxygen molecule when exposed to extreme heat, and then retrieve an oxygen molecule once it cools down.

The machine is designed with a chamber on each side. One side is hot, the other cool. Running through the center is a set of 14 Frisbee-like rings rotating at one revolution per minute. The outer edge of each ring is made up of an iron oxide composite supported by a zirconium matrix. Scientists use a solar concentrator to heat the inside

of one chamber to 1,500 ° C, causing the iron oxide on one side of the ring to give up oxygen molecules. As the affected side of the ring rotates to the opposite chamber, it begins to cool down and carbon dioxide is pumped in. This cooling allows the iron oxide to steal back oxygen molecules from the CO₂, leaving behind carbon monoxide. The process is continually repeated, turning an incoming supply of CO₂ into an outgoing stream of carbon monoxide.

Miller says the same process can be used to produce hydrogen, the only difference being that water, instead of carbon dioxide, is pumped into the second chamber. The two separately retrieved gases--hydrogen and carbon monoxide--are then mixed together to make syngas, which can be used to make a "drop-in replacement" for traditional fuels, says Miller.

Diver originally designed the machine with the hydrogen economy in mind. The idea was to avoid the inefficiency of electrolysis and build instead a solar heat engine that could produce hydrogen and oxygen directly, cutting out electricity as the middleman. It's an approach also being pursued by researchers in Japan, France, and Germany.

But the Sandia team soon realized that the same process could turn CO₂ into carbon monoxide. Even if the hydrogen economy didn't take off, they still had a way to make the fuels we depend on today in a way that limits the impact of burning coal and natural gas for electricity and other industrial processes.

Diver says the challenge now is to improve the efficiency of the system. If the Sandia team can demonstrate higher efficiency, "it could be a significant step forward," said [Vladimir Krstic](#), director of the Centre for Manufacturing of Advanced Ceramics and Nanomaterials at Queen's University in Kingston, Ontario.

Scientists figure it will be 15 to 20 years before the technology is ready for market. In the meantime, the goal is to develop a new generation prototype every three years that shows an increase in solar-to-fuel conversion efficiency and a decrease in cost. Part of that will come from the development of new ceramic composites that release oxygen molecules at lower temperatures, allowing for more of the sun's energy to be converted into hydrogen or carbon monoxide.

"Our short-term goal is to get this to a few percent efficiency," says Miller. "It might seem like a low number, but we like to compare that to photosynthesis, which is actually a very inefficient way to use sunlight."

He says the theoretical maximum efficiency for photosynthesis is around 5 percent, but

in the real world it tends to fall to around 1 percent. "So we may be starting very low, but we'd like to keep it in the context of what we have to beat. Ultimately, we believe we have to get in the range of 10 percent sunlight-to-fuels, and we're a long way from doing that."

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