Novel System for Storing Renewable Energy to Achieve On-Demand Delivery of Electricity

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Engineers at MIT have created a conceptual design for a system to store renewable energy, such as wind and solar power, and to perform on-demand delivery of the energy back into an electric grid. It would be possible to design the system to power a small city not just when the wind is high or the sun is up, but perpetually.

MIT researchers propose a concept for a renewable storage system, pictured here, that would store solar and wind energy in the form of white-hot liquid silicon, stored in heavily insulated tanks. (Image credit: Duncan MacGruer)

The innovative system has the ability to store heat produced by excess electricity from wind or solar power in large tanks of white-hot molten silicon. It then converts the light from the glowing metal back into electricity whenever it is required. The engineers predict that such a system would be extremely affordable compared to lithium-ion batteries, which have been put forward as a practical, but expensive, method for the storage of renewable energy. They also predict that the cost of the system would be about half of the cost of pumped hydroelectric storage—the most inexpensive form of grid-scale energy storage developed until now.

> *Even if we wanted to run the grid on renewables right now we couldn't, because you'd need fossil-fueled turbines to make up for the fact that the renewable supply cannot be dispatched on demand. We're developing a new technology that,*

if successful, would solve this most important and critical problem in energy and climate change, namely, the storage problem.

Asegun Henry, Robert N. Noyce Career Development Associate Professor, Department of Mechanical Engineering, MIT

Henry and his collaborators have published their design in the *Energy and Environmental Science* journal on December 5th, 2018.

Record temps

The new storage system arises from a project in which the engineers searched for means to improve the efficiency of a form of renewable energy called concentrated solar power. In contrast to traditional solar plants in which solar panels are used to convert light directly into electricity, concentrated solar power mandates the use of enormous fields of huge mirrors that concentrate sunlight onto a central tower, where the light is transformed into heat that is ultimately changed into electricity.

"*The reason that technology is interesting is, once you do this process of focusing the light to get heat, you can store heat much more cheaply than you can store electricity*," noted Henry.

Concentrated solar plants include large tanks filled with molten salt to store solar heat, where the salt is heated to high temperatures of about 1000 °F. When there is a need for electricity, a heat exchanger through which the hot salt is pumped transfers the heat from salt into steam. Then, the steam is turned into electricity by a turbine.

"*This technology has been around for a while, but the thinking has been that its cost will never get low enough to compete with natural gas*," stated Henry. "*So there was a push to operate at much higher temperatures, so you could use a more* *efficient heat engine and get the cost down*."

However, if the salt is heated by operators much beyond existing temperatures, the stainless steel tanks in which the salt is stored would be corroded by the salt. Therefore, Henry and his colleagues were on the hunt for a medium other than salt that could store heat at considerably higher temperatures. At first, they suggested the use of a liquid metal and ultimately settled on silicon—the most abundant metal on Earth, which has the ability to endure incredibly high temperatures of more than 4000 °F.

Last year, the engineers created a pump that could endure such sweltering heat and could potentially pump liquid silicon through a renewable storage system. The pump has the highest heat tolerance on record—an achievement that has been noted in "The Guinness Book of World Records." From the time that development was achieved, the engineers have been designing an energy storage system that could be equipped with such a high-temperature pump.

"Sun in a box"

Currently, the team has outlined its concept for an innovative renewable energy storage system, termed TEGS-MPV, for Thermal Energy Grid Storage-Multi-Junction Photovoltaics. Rather than using fields of mirrors and a central tower to concentrate heat, they suggest transforming electricity produced from any renewable source, such as wind or sunlight, into thermal energy, by means of Joule heating—a process by which an electric current passes through a heating element.

It was possible to couple the system with prevalent renewable energy systems, such as solar cells, to absorb excess electricity during the day and store it for use later on. Take, for example, a small town in Arizona that obtains a portion of its electricity from a solar plant.

> *Say everybody's going home from work, turning on their air*

conditioners, and the sun is going down, but it’s still hot. At that point, the photovoltaics are not going to have much output, so you’d have to have stored some of the energy from earlier in the day, like when the sun was at noon. That excess electricity could be routed to the storage system we’ve invented here.

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The system would include a large, 10-m-wide, heavily insulated tank made of graphite and filled with liquid silicon, maintained at a “cold” temperature of almost 3500 °Fahrenheit. This cold tank is then connected to a second, “hot” tank by a bank of tubes exposed to heating elements. Once the electricity from the solar cells in the town reaches the system, this energy is transformed into heat in the heating elements. At the same time, liquid silicon which is pumped out of the cold tank further heats up when it passes through the bank of tubes exposed to the heating elements, and into the hot tank. Here, the thermal energy is now stored at a considerably higher temperature of about 4300 °F.

When there is a need for electricity, for instance, after sunset, the hot liquid silicon—so hot that it glows white—is pumped through an array of tubes that emit the light. Subsequently, that light is turned into electricity by specialized solar cells, called multijunction photovoltaics. This electricity can be supplied to the town’s grid. The now-cooled silicon can be pumped back into the cold tank until the subsequent round of storage—functioning effectively as a large rechargeable battery.

“*One of the affectionate names people have started calling our concept, is ‘sun in a box,’ which was coined by my colleague*

Shannon Yee at Georgia Tech," stated Henry. "*It's basically an extremely intense light source that's all contained in a box that traps the heat*."

A storage key

According to Henry, thick and strong tanks, which can insulate the molten liquid within, would be needed for the system.

"*The stuff is glowing white hot on the inside, but what you touch on the outside should be room temperature*," stated Henry.

He has suggested that the tanks should be made of graphite. However, concerns are that silicon, at such high temperatures, would react with graphite to generate silicon carbide, which could corrode the tank.

In order to test this possibility, the engineers fabricated a miniature graphite tank and filled it with liquid silicon. Upon maintaining the liquid at 3600 °F for around 60 minutes, although silicon carbide was produced, rather than corroding the tank, it formed a thin, protective liner.

"*It sticks to the graphite and forms a protective layer, preventing further reaction*," stated Henry. "*So you can build this tank out of graphite and it won't get corroded by the silicon*."

The team also discovered a solution to another problem: Since it is necessary for the system's tanks to be very large, it would not be feasible to construct them from a single piece of graphite. Rather, if they were made from multiple pieces, it would be a must to seal them in a way to prevent the molten liquid from leaking out. In their study, the engineers showed that it is possible to prevent any leaks by screwing pieces of graphite together with carbon fiber bolts and sealing them with grafoil—flexible graphite that functions as a high-temperature sealant.

The team predicts that a single storage system could be used to power a small city of about 100,000 entirely using renewable energy.

> *Innovation in energy storage is having a moment right now. Energy technologists recognize the imperative to have low-cost, high-efficiency storage options available to balance out nondispatchable generation technologies on the grid. As such, there are many great ideas coming to the fore right now. In this case, the development of a solid-state power block coupled with incredibly high storage temperatures pushes the boundaries of what's possible.*
>
> *Addison Stark, Associate Director for Energy Innovation, Bipartisan Policy Center; Staff Director, American Energy Innovation Council*

Henry reiterates that the design of the system is geographically limitless, indicating that it is possible to site it anywhere, without any regard to the landscape of a location. This is contrary to pumped hydroelectric—which is the existing cheapest form of energy storage that needs locations that can accommodate large waterfalls and dams, to store energy from falling water.

"*This is geographically unlimited, and is cheaper than pumped hydro, which is very exciting*," stated Henry. "*In theory, this is the linchpin to enabling renewable energy to power the entire grid*."