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Storing Renewable Energy, One Balloon at a Time

To decarbonize the electrical grid, companies are finding creative ways to store energy during periods of low demand.

By Amos Zeeberg
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Central Sardinia is not generally considered a hotbed of innovation: Arid and rural, some of its road signs riddled with bullet holes made by target-practicing locals, the setting recalls a Clint Eastwood western. Yet in Ottana, on the brownfield site of a former petrochemical plant, a new technology is taking shape that might help the world slow climate change. The key component of this technology is as unlikely as the remote location: carbon dioxide, the chief cause of global warming.

Energy Dome, a start-up based in Milan, runs an energy-storage demonstration plant that helps to address a mismatch in the local electricity market. “In Sardinia during the day, everyone goes to the sea,” Claudio Spadacini, chief executive of Energy Dome, said. “They don’t use electricity, but there’s a lot of supply,” he added, referring to the Italian island’s abundant sunlight.

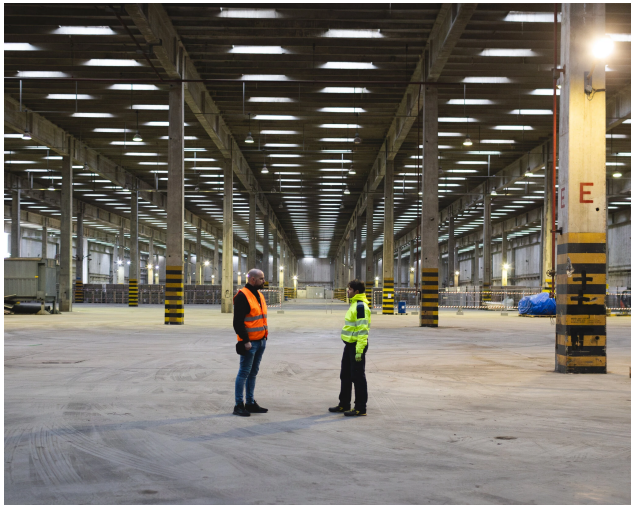
Energy Dome uses carbon dioxide held in a huge balloon, the “dome” in the company’s name, as a kind of battery. During the day, electricity from the local grid, some produced by nearby fields of solar cells, is used to compress the carbon dioxide into liquid. At night, the liquid carbon dioxide is expanded back into gas, which drives a turbine and produces electricity that is sent back to the grid.

Solar and wind power are fast-growing renewable sources, but they rely on nature’s intermittent schedule

to produce electricity. Many researchers and policymakers say that storing such energy until needed, for hours or even days, is key to transitioning economies away from fossil fuels. “Advancing energy-storage technologies is critical to achieving a decarbonized power grid,” Jennifer M. Granholm, the U.S. energy secretary, said in a 2022 statement, when her department announced that it would commit more than $300 million for long-duration energy storage.

Companies are developing and marketing varied and creative ways to store renewable energy: liquefying carbon dioxide, de-rusting iron, heating towers filled with sand to temperatures almost hot enough to melt aluminum. But predicting our energy-storage needs in the future, after a huge energy transformation, is a daunting prospect, and which of these approaches, if any, will prove effective and profitable is unclear.

“There is a real urgency around decarbonizing electricity on a timeline that is much faster than we’ve contemplated in the past,” said Elaine Hart, founding principal with Moment Energy Insights LLC, a clean-energy consultancy. “We don’t need technologies like long-duration energy storage or hydrogen today, but we might need them on a large scale in the next 15 to 20 years, so we’re in a critical time for their development.”



The construction of a warehouse for Energy Dome, which uses a carbon dioxide compressor; the control room of Ottana Energia, a former petrochemical plant next door.

Supplanting the Standards

For decades, many electric utilities responded to fluctuating demand by using pumped hydroelectric storage, which generates electricity when demand for electricity is high, then pumps water from a lower reservoir to a higher one to store energy when there is excess supply. Some utilities are now installing new pumped hydroelectric storage to balance solar and wind production. Many other utilities are installing arrays of lithium-ion batteries to store excess energy produced by renewables, and that market is booming.

But these storage methods have limitations. Pumped hydroelectric requires — and alters — hilly landscapes, and the facilities cost a lot to build. Lithium is a limited resource that is often dirty to mine, and it becomes excessively expensive when designed to store energy for much more than four hours, which may be an important capability if intermittent sources provide the majority of a grid's power.

“Long-duration storage generally doesn’t become necessary until you get to high levels of wind and solar,” said Scott Murtishaw, executive director of the California Energy Storage Alliance, an industry group that advocates more storage on electric grids. “But it is critical if you’re committed to really decarbonizing the grid.”

Westinghouse Electric, a supplier of products and services to nuclear plant operators, says that its new energy-storage technology, which depends on carbon dioxide, like Energy Dome’s approach, is an improvement on pumped hydro and lithium-ion. The company’s technology works like a heat pump, using carbon dioxide in a supercritical state — at such high temperature and pressure that it acts like a hybrid of a liquid and a gas — to transfer heat, produced by excess electricity, into concrete blocks. Later on, the heat stored in the blocks is used to generate electricity. “It’s kind of ironic that carbon dioxide is the material that led to a lot of the innovation here,” John Battaglini, Westinghouse’s vice-president of new market development for the Americas, said.

In September, Westinghouse announced that it would build a 100-megawatt storage facility in Alaska, enough to supply about 80,000 average American homes with electricity for up to 12 hours. He added that the facility would cost about half that of one using lithium-ion batteries: “We feel very, very good about the economics.”

Going Long

Workers on power trowels level a section of what will become the floor of Form Energy's factory in Weirton, W.Va. Kristian Thacker for The New York Times

Some companies are anticipating a time when most of our electricity comes from renewables and grids that require much longer-duration storage. Form Energy, based in Somerville, Mass., aims to provide electricity for 100 hours, after some studies found that grids based on renewables would need to be able to provide backup energy for about that long.

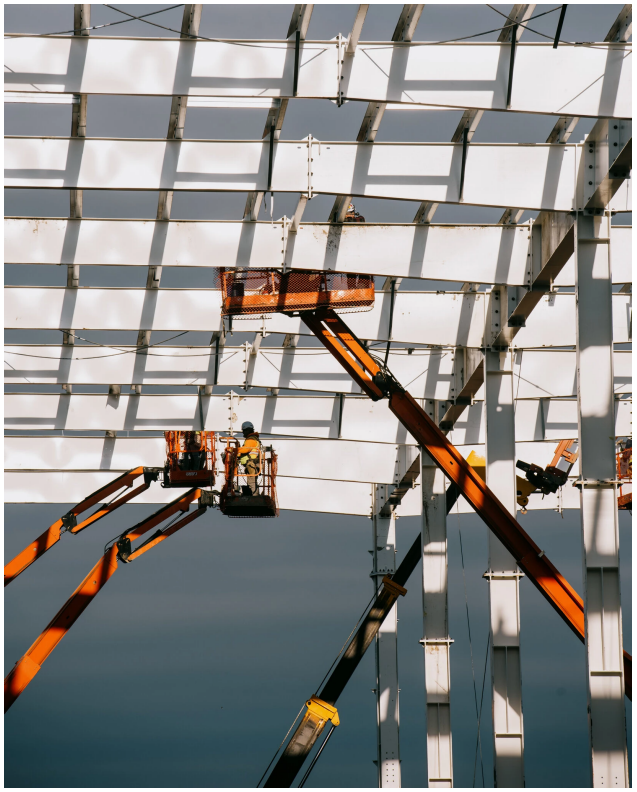
To provide that much capacity affordably, Form had to find a very low-cost storage process, so the company turned to a cheap, ubiquitous material that undergoes a well-understood reaction: the oxidation, or rusting, of iron. As iron rusts, it produces energy; by feeding energy back into the system, Form can reverse the reaction and store energy, which can be released later by rusting the iron again.

Form's storage system uses a specially tuned form of iron to maximize reversibility and durability. "That's where there's been a lot of invention on our side," Mateo Jaramillo, Form's co-founder and chief executive, said. "That's one of the key tricks — our trade secret."

Form says it can install storage capacity at a price that's roughly one-tenth that of lithium-ion batteries. "The trade-off is lower cost, lower efficiency," Mr. Jaramillo said. "Our modeling shows we've reached the right level of cost and efficiency."

Last year, Form announced agreements to build plants in six states, each with 100-hour capacity, providing 55 total megawatts. The company is also building a battery-manufacturing facility in Weirton, W.Va., on the site of a former steel plant that declined in recent decades, depressing the local economy. West Virginia's

governor, Jim Justice, a Republican, visited the site last December for the signing of a bill that appropriated $105 million from the state to help build the facility.




Mateo Jaramillo, chief executive of Form Energy, which says it can install storage capacity at roughly one-tenth the cost of lithium-ion batteries. “The trade-off is lower cost, lower efficiency,” he said.

The Dunkelflaute and Schwarzenegger Effects

Corre Energy, based in the Netherlands, is working on storing energy for several days by compressing air to high pressure inside salt caverns, where natural underground salt deposits are dissolved away to leave

large empty pockets.

In June, Corre announced a deal in Germany to provide up to 640 megawatts of electricity, enough to supply about 1.6 million German homes, for up to 125 hours, at about one-tenth the cost of lithium-ion. Corre's partner is developing four caverns there now, with two set to go into operation in 2027.

Corre says that the demand for long-duration storage is high in Northern Europe, which is keen on renewables but prone to multiday periods of little wind and sunlight, known in green-energy circles (and German) as dunkelflaute.

"We're addressing that accelerating demand" for long-duration storage, Keith McGrane, chief executive of Corre, said. "It's the dunkelflaute effect."

Some companies are pursuing approaches that can sound surprisingly simple. A Finnish start-up called Polar Night Energy uses excess electricity to heat sand to temperatures as high as 1,100 degrees Fahrenheit. The sand can later be used to provide up to 100 hours of heat to local homes and businesses. Earlier this month, the company announced a deal to build a storage facility for the town of Pornainen, with a projected reduction of emissions by nearly 70 percent. The company is also developing a method to start providing electricity in addition to heat.

Tommi Eronen, the chief executive of Polar Night Energy, spoke in May at a climate conference in Vienna. He promoted the company to other green-leaning attendees, including the conference founder, Arnold Schwarzenegger. "It was fun to hang out with Arnold for three days. He was a nice guy," Mr. Eronen said. "Of course, we disagree on some points. I'm more into cycling than driving cars."

Making a New Market

The site in Ottana of the future full-scale version of Energy Dome's battery. Gaia Squarci for The New York Times

Form Energy's factory is being built on the site of a former steel plant. Kristian Thacker for The New York Times

The road from concept to company and infrastructure is always precarious, and long-term energy storage faces particular challenges.

Utilities have used short-term storage for decades, but there has never been much of a market for storage over many hours or days. It's not clear how storage companies could make enough money to pay for the huge increase in storage that proponents say is necessary. "The biggest challenge with long-duration

energy storage is that the economics are lousy," said James Bushnell, an economist at the University of California, Davis, who studies energy. "If your storage is sitting charged for weeks or months, that's much less revenue."

Mr. Battaglini of Westinghouse said the company was exploring this challenge with regional utilities and independent system operators, the nonprofit groups that oversee electric grids. Form Energy has created models to show electric utilities how to use long-duration batteries so that they're profitable.

"You can't know what you need if you can't model it," Mr. Murtishaw said. "It's like the iPhone — a product you didn't know you needed until someone made it."

Another issue for the new storage approaches is the dominance and continued improvement of lithium-ion batteries. As manufacturers improve the design of batteries and scale up their production, the cost continues to decrease, gradually making lithium-ion more economical for longer durations.

These challenges have hurt some makers of long-term storage. Azelio, a company that stored energy as heat in an aluminum alloy inside modular units, declared bankruptcy in July.

Still, some providers of long-duration storage say that the market is growing fast and that they are ramping up construction to meet the demand.

In Ottana, diggers are clearing away blackened rubble from the remains of old industrial buildings to make room for a commercial-scale Energy Dome storage facility that will hold 40 times as much energy as the adjacent pilot plant. Despite the superficial differences, Mr. Spadacini described the shiny Energy Dome facility as a sort of descendant of the dirtier oil-fueled generator that used to run on the same site. "The energy of oil was energy from the sun, and it was stored at some efficiency in oil," he said, noting that oil derives mostly from photosynthetic plants. "We need to store and use that energy as directly and efficiently

as possible.”

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