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Clean Energy Breakthroughs: Grid-Scale Energy Storage

Bicameral Task Force on Climate Change

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About the Series

The Bicameral Task Force on Climate Change is issuing a series of fact sheets examining emerging energy technologies that could play a significant role in the clean energy economy of the future. The transition to a clean energy economy presents technical challenges for which scientists and researchers across the country and around the world are developing solutions. Each fact sheet in the Clean Energy Breakthroughs series will examine a technical challenge, describe the opportunities it presents, and highlight new technologies that are being developed to address the challenge. Some of the profiled technologies will ultimately succeed in the commercial market while others may not.

This Clean Energy Breakthrough examines the progress being made on grid-scale energy storage.

The Challenge

Today's electric grid has a limited ability to store energy. As a result, electricity must be generated in the precise amount needed to meet demand at any given time. Some clean energy technologies, such as wind and solar power, are intermittent in nature. That is, they generate electricity when the resource (wind or sun) is available, not necessarily when a grid operator would like to schedule the generation to be available. When these forms of electricity generation make up a small percentage of the total generation, their integration into the grid is typically easily facilitated. However, integrating larger percentages of intermittent generation into the grid can pose challenges to the grid operators.

Flexible, affordable, large-scale energy storage would allow excess energy from variable resources to be stored until that energy is needed. This would further enable the widespread deployment of wind and solar generation, substantially reducing carbon emissions from the electric sector while boosting clean energy manufacturing and jobs in the United States.

The Technologies

During the preparation of this fact sheet, staff consulted with numerous researchers and academic institutions. Teams of scientists and researchers are developing a number of promising energy storage technologies that have the potential to operate at grid-scale. This fact sheet does not attempt to describe each of the promising technologies that are currently in development or commercialization. Instead, two technologies are discussed below in order to illustrate the innovative clean energy work currently being undertaken.

MIT/Ambri Liquid Metal Battery

A MIT team led by Professor Donald Sadoway is developing a rechargeable liquid metal battery. Traditional batteries have two solid electrodes separated by a liquid electrolyte and a solid separator. Ions move from one solid electrode through the electrolyte to the other solid electrode to generate electricity. To recharge the battery, the process is reversed: electricity is added to force the ions to move back to the original electrode. MIT's liquid metal battery is different because it operates at very high temperatures with two liquid metal electrodes and a molten salt electrolyte. The three layers self-separate by density and float on top of each other. The design is inspired by the process of aluminum smelting and is essentially smelting in reverse.

The liquid metal battery has several potential advantages over traditional batteries. First, because it has no separator, which can dictate the size of the battery, there is theoretically no limit to the size of the liquid metal battery. Second, the molten salt electrolyte has very high conductivity (passes more current) compared to other electrolytes. Third, the components of the liquid metal battery were specifically selected and designed to be low-cost and earth-abundant. Finally, the use of liquid electrodes avoids the capacity degradation experienced by traditional rechargeable batteries. Over hundreds of charging and recharging cycles, a solid electrode contracts and expands and the electrode gradually breaks down. Liquid metal electrodes are not vulnerable to this deterioration so there is no apparent limit to the number of times a liquid metal battery can be recharged. The MIT team has produced battery cells that have undergone the discharge-recharge cycle 1,000 times with no degradation. That translates into about three years of use if the liquid metal battery cycled once per day in a grid application. MIT projects the full battery lifetime will be 10 to 15 years, which is much longer than the lifetime of other currently available batteries, such as lithium ion batteries.

The MIT team formed a company called Ambri to commercialize the technology. Bill Gates, the French energy company Total, and Khosla Ventures are all investors. Ambri's battery cells can be stacked into refrigerator-sized modules, which are then placed in a 40-foot shipping container for a system with two megawatt hours of storage capacity. According to Ambri, the system can dispatch stored electricity in milliseconds. Ambri plans to deliver commercial prototypes in 2014 and move towards full commercialization in 2015.

Proton Regenerative Fuel Cells

A company called Proton Energy Systems is developing an energy storage device that produces hydrogen fuel when there is excess electricity and then uses the hydrogen to generate electricity when it is needed. There are two basic components to the system: an electrolyzer and a fuel cell. The electrolyzer uses electricity to convert water into hydrogen and oxygen. The fuel cell converts the hydrogen and oxygen back into water to create an electrical current.

Proton's unique technology is the electrolyzer. The company purchases commercially available fuel cells and integrates them into its electrolyzer systems.

The Proton electrolyzer uses an ion exchange membrane to split water into hydrogen and oxygen. Traditional electrolyzers use acidic membranes that require expensive materials like titanium and expensive catalysts like platinum. Proton's technology will use an inexpensive alkaline membrane, which allows the cell parts to be made of stainless steel instead of titanium and allows nickel and iron to be used for the catalysts instead of platinum. Proton's catalyst materials are an order of magnitude less expensive than traditional materials. According to Proton, its overall alkaline membrane electrolyzer will be at least 50% cheaper than its acidic membrane electrolyzer.

Currently, Proton sells a 200 kilowatt acidic membrane electrolyzer that can produce 65 kilograms of hydrogen per day. It is used for industrial applications and for fueling hydrogen fuel cell vehicles. Proton is developing a one megawatt scale acidic membrane electrolyzer to launch commercially in late 2014. The one megawatt system will be composed of many cells stacked in a 40-foot shipping container and could be linked with other such modules to increase the scale of the hydrogen production and energy storage capacity. Over the next three to five years, Proton plans to shift to its new alkaline membrane electrolyzer technology, which should be able to drop into the storage systems that had been designed to use acidic membrane electrolyzers.

The Potential

Energy storage technologies like the MIT/Ambri liquid metal battery and the Proton regenerative fuel cell have multiple potential applications. They can support the increased use of renewable energy by smoothing the power from these intermittent sources to provide a constant energy supply, allowing renewable energy generated during periods of low demand to be stored and later released during periods of peak demand. Energy storage can shave peak demand more generally, reducing the need for new peaking generation capacity. Storing energy closer to where it will be used also can postpone or eliminate the need to build new transmission lines and reduce congestion on existing transmission lines. In addition, because of their fast dispatch times, energy storage technologies can increase the reliability of the electric grid and reduce the frequency of power interruptions, which cost consumers approximately $80 billion a year.[1]

The market potential for cost-effective energy storage technologies is huge. Sandia National Laboratories has calculated the potential U.S. market demand for energy storage for just one application – storing excess renewable energy - to be more than 36,000 megawatts over ten years.[2] The worldwide market for grid-scale energy storage is expected to exceed $30 billion per year by 2022.[3]

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[1] U.S. Department of Energy, *Electric Power Industry Needs for Grid-Scale Storage Applications* (Dec. 2010).

[2] Sandia National Laboratories, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide* (Feb. 2010).

[3] Business Wire, *Energy Storage on the Grid Will Surpass $30 Billion in Annual Market Value by 2022, Forecasts Pike Research* (Oct. 24, 2012).