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Department of Energy

Committee on Science and Technology

Energy and Environment Subcommittee

U.S. House of Representatives

October 3, 2007

Mr. Chairman and Members of the Subcommittee thank you for this opportunity to testify on behalf of the Department of Energy (DOE) on "Energy Storage Technologies: State of Development for Stationary and Vehicular Applications."

The Department of Energy places great emphasis on the promise of energy storage and is researching a variety of storage technologies. Within DOE, applied research into energy storage technologies primarily occurs within two offices: the Office of Energy Efficiency and Renewable Energy (EERE) and the Office of Electricity Delivery and Energy Reliability (OE). EERE supports the Advanced Energy Initiative by advancing technologies such as biomass and biofuels, solar power, wind power, advanced vehicles, and hydrogen fuel cells. Moreover, OE performs research and development, and conducts demonstrations on stationary storage applications related to the electric system. OE leads national efforts to modernize the electricity delivery system; enhance the security and reliability of America's energy infrastructure; and facilitate recovery from disruptions to energy supply. Additionally, basic research supported by the Office of Science can lead to solutions to technology challenges and enhance the energy, power, shelf life, cycle life, cost, and reliability of energy storage systems. These functions can help DOE achieve its strategic goal of promoting a diverse supply and delivery of reliable, affordable, and environmentally responsible energy.

Vehicular Storage

The Department is committed to developing technologies that can help advance President Bush's Twenty in Ten Plan, a legislative proposal to displace twenty percent of expected gasoline usage in 2017 through greater use of clean, renewable fuels and increased vehicle efficiency. The development and use of Plug-in Hybrid Electric Vehicles (PHEVs) will help us work toward the goal of this Plan. PHEVs present a unique opportunity for the Nation to transition from using exclusively oil, much of which comes from foreign sources, to fueling our vehicles, in part, with domestically-produced electricity from the grid. High energy-density batteries are key to the successful commercial development and deployment of these vehicles. PHEVs have the potential to displace a large amount of gasoline if they deliver up to 40 miles of electric range without recharging – a distance that would include most daily roundtrip commutes, since more than 70 percent of Americans drive less than 40 miles per day. That is why EERE is increasing its investment in this technology. Propulsion over a 40, or even a 20 mile range, will require storage technologies with high specific power and energy, deep discharge, and long cycle life. Thus, EERE is researching lithium ion batteries, which have two to three times the energy density (300-400 kWh/L) compared to the nickel-metal hydride batteries currently in use for today's hybrid electric vehicles.

The Department has also made progress on the issue of safety in lithium ion batteries for automobiles; however, other interrelated factors such as durability, power density, and cost must also be addressed before the technology can become commercially viable. Currently, the program is focusing on researching materials and non-flammable electrolytes so future lithium ion technologies will become more tolerant to abuse. The FY 2008 Congressional Budget includes $42 million to support advanced battery R&D, compared to $41 million in the FY07 operating plan.

Over the next three years, pending appropriations from Congress, DOE plans to invest $17.2 million in PHEV battery development projects that aim to address critical barriers to the commercialization of PHEVs, specifically battery cost and battery life. Five projects were recently selected for negotiation of awards under DOE's collaboration with the United States Advanced Battery Consortium. DOE will also spend nearly $2 million on a study exploring the future of PHEVs. The study will: evaluate how PHEVs would share the power grid with our Nation's other energy needs; monitor the American public's evolving view of PHEVs; and provide the first national-level empirical data on how driving behavior differs with these vehicles compared to conventional gasoline, diesel, and hybrid vehicles. It will also assess a possible reduction of greenhouse gas emissions with the increased use of PHEVs and identify how automakers could optimize PHEV design to increase performance while also reducing cost. As part of the study, researchers and auto industry partners will build a simulation model to test different PHEV design concepts.

The possibility of increasingly providing fuel for the Nation's cars and light trucks with domestically-produced electricity and reducing the use of oil, much of which is imported, is very exciting. A previous study from DOE's Pacific Northwest National Laboratory suggests that up to 84 percent of U.S. cars, pickup trucks, and sport utility trucks could be powered by plugging into the existing electricity infrastructure and by utilizing this battery capacity to level loads.

It is clear that PHEVs will have impacts far beyond the transportation sector and become an integral, although not always connected, element of our "stationary" electric system. When considering the potential impact of widespread use of PHEVs on our Nation's energy demand, it is essential to understand and address broader electric system impacts. For example, although ample generation capacity may exist on an aggregate scale to meet charging needs, how would PHEVs impact voltage regulation requirements? Or, how would that generation capacity vary by region? Preparing answers today to questions such as these will allow PHEVs to successfully evolve from functioning solely as "people movers" to becoming "stationary" power sources for residential consumers that can also support utilities.

Further studies will be conducted in partnership with the automotive manufacturers, national laboratories, utilities, and universities to define PHEV battery requirements; consumer behavior for charging vehicles and managing residential loads; grid interface and interconnection requirements; and the effects PHEVs would have on the grid. The Department is expecting preliminary results from these studies in the summer of 2008.

Finally, through Executive Order 13423 *Strengthening Federal Environmental and Energy Management*, the President has committed the Federal government to add PHEVs to its own fleet as the vehicles become commercially available at a cost reasonably comparable, on the basis of life-cycle cost, to non-PHEVs.

<u>Stationary Storage</u>

Stationary storage systems provide energy management, complement renewable resources, and can improve power quality and reliability. This includes “ride-through” of power quality events such as voltage sags that range in length from cycles to seconds to providing minutes to hours of electricity as an uninterruptible power source. A study by the Electric Power Research Institute found that 98 percent of power quality events last less than 15 seconds. Power quality problems are defined as subtle deviations in the quality of delivered electricity (sometimes lasting only tens of milliseconds in length), often seen as the dimming or flickering of lights. Short-term events lasting up to five minutes can cause hours of downtime in operations. A detailed survey of cost and outage data throughout the U.S. conducted by Lawrence Berkeley National Laboratory estimates the cost of such outages to be some $53 billion annually (LBNL 55718). Energy storage can be drawn upon to mitigate power quality problems and prevent momentary outages, and as such, can be viewed as “insurance coverage,” mitigating risk. Stationary storage systems that are currently being used include conventional batteries (Ni-Cd, lead acid), compressed air, pumped hydro, flow batteries, sodium sulfur and metal-air batteries, fly wheels, and capacitors. These systems are critical bridging technologies whose applications including load balancing and improving overall system performance.

<u>Stationary Storage – Residential, Commercial or Industrial Applications</u>

Varying storage technologies can be used in residential, commercial, or industrial applications. Whether an energy storage device is paired with a renewable technology or simply installed alone at a customer’s site, it can serve a number of valuable functions:

acting as a balancing technology to solve intermittence issues, serving as an uninterruptible power supply (UPS), or leveling consumer's demand. Energy storage and photovoltaic (PV) hybrid systems, for example, would provide customers the flexibility to charge their storage device and discharge their stored power in combination with the PV system to satisfy their peak demand requirement. This system can begin to address power quality issues.

Many demonstrations are ongoing. The Department, in partnership with New York State Energy Research and Development Agency (NYSERDA), has funded a residential energy storage and propane fuel cell demonstration project that uses an 11kW, 20 kWh Gaia Power Technologies "PowerTower" energy storage system in conjunction with a Plug Power "GenSys" propane fuel cell. The demonstration illustrated demand reduction 1) when the "PowerTower" provides an energy boost if the user load exceeds a preset threshold and 2) when the PlugPower propane fuel cell becomes a primary electricity source in conjunction with the PowerTower. This system was in operation from January 2006 to July 2006. The partners include the Delaware County Electric Cooperative, Gaia Power Technologies and EnerNex Corporation.

Another project being funded by DOE and NYSERDA is the ongoing Flywheel-Based Frequency Regulation Demonstration project (FESS), located at an industrial site in Amsterdam, New York. It regulates grid frequency by utilizing a high-energy flywheel storage system consisting of seven Beacon Power flywheels that have been adapted to operate on the National Grid (formerly Niagara Mohawk) distribution system. This system will be capable of providing 100 kW of power for frequency regulation, about $1/10^{th}$ the scale of the needed final product. Frequency regulation can serve to balance the ever-changing differences between electricity generation and load. Using flywheels to provide frequency regulation will allow demand to be met quickly and will allow generators to operate at higher output for optimum efficiency and lower emissions.

Stationary Storage – Utility Applications

As it exists today, the U.S. electric utility infrastructure consists of a vast network of power plants and transmission and distribution lines that span the entire continent. This system requires that the generation and consumption of electric energy be instantaneously balanced. As the load changes, generators must ramp up or down to meet demand for electricity. Yet an equipment failure can cause an instantaneous imbalance between generation and load, which could potentially lead to other system damage or a power outage. Using advanced storage technologies to compensate for changes in demand for electricity could improve grid reliability and stability.

To date, large-scale applications of energy storage to the electric system have not been extensive. Roughly 2.5 percent of the total electric power currently delivered in the United States passes through energy storage devices, and it is primarily limited to pumped hydroelectric storage. The percentages are somewhat greater in Europe and Japan, at 10 percent and 15 percent, respectively. The strategic placement of electricity storage systems could provide: 1) load leveling (within a regional control area), allowing generators to operate closer to their optimum economical and environmental set points; 2) reduce electric transmission congestion; 3) provide stabilizing energy to minimize disturbances on the transmission and distribution system; and 4) provide ancillary services such as spinning reserve, voltage, and frequency regulation.

The Department has also invested in several storage demonstrations for utility applications. For example, in partnership with the California Energy Commission and ZBB Energy Corporation (Menomonee Falls, Wisconsin), DOE is planning to demonstrate a 2MW, 2MWh zinc-bromine battery at a Pacific Gas & Electric substation that reduces distribution system congestion. The battery installation operates in stand-by mode to supply extra power when the substation reaches overload conditions. The installation will be mobile so that it can be deployed to wherever the most serious peaking loads occur.

In partnership with Palmdale Water District (Palmdale, California), the Department is demonstrating a 450 kW supercapacitor device that will minimize the impact of variable winds on a 950 MW wind turbine attached to the microgrid for the Palmdale, California, Water District's treatment plant. During power outages, this energy storage will also provide ride-through for critical loads until emergency generation can be brought online.

In addition to providing reliable energy for the microgrid, the project will also help reduce transmission and distribution congestion in the area.

Energy storage is just one way to increase the reliability and resiliency of the electric grid. When storage devices are paired with so-called "intelligent" smart grid technologies, the grid could fully take advantage of renewable technologies, allow for increased numbers of PHEVs, and enable demand response. Like storage, smart grid technologies could have a revolutionary impact on our electric system. The result will be new innovative tools and techniques, better sensors, improved diagnostics, and enhanced equipment design and operation that will increase energy efficiency, system utilization, reliability, and security. Smart grid technologies such as smart appliance chips, advanced meters, and energy management systems would be located at the customer level. The distribution system would have to include smart grid technology through intelligent agents and controls and the transmission system would have to incorporate wide area system monitoring.

Collaboration with the Office of Science

The Department recognizes that fundamental, basic research into the future of energy storage materials and systems is still required and can be a critical asset that accelerates our progress. We still seek: a greater understanding of storage device performance degradation and failure mechanisms; the achievement of higher power density and longer life; enhanced energy density; new electrolytes for high-efficiency and high-current operation; and safety and abuse tolerance. Developing solutions to these technology challenges could enhance the energy, power, shelf life, cycle life, cost, and reliability of energy storage systems.

Thus, the OE and EERE continue to coordinate with the Office of Science in several research areas, including storage, to ensure the transfer of basic research to applied R&D. OE would like to expand this coordination in target materials research for electrical energy storage (EES). This R&D focus area was the subject of an Office of Basic Energy Sciences workshop held by EERE, OE, and the Office of Science during April 2-4, 2007, to explore research needs and opportunities. The findings, which noted that revolutionary breakthroughs in EES have been singled out as perhaps the most crucial need for the Nation's secure energy future, can be found in the workshop report, *Basic Research Energy Needs for Electrical Energy Storage.*

The proposed coordinated basic-applied EES research effort aims to underpin the applied technology research with transformational basic sciences, while at the same time energizing the basic research with insights and opportunities that come from advances in applied research programs. This process will be initiated in FY 2008 and result in designated research projects in FY 2009. The goal is to facilitate the successful translation of breakthrough knowledge gained in basic research to applied technologies, and to cultivate the U.S. capabilities to maintain a global leadership in energy storage systems for transportation and electricity transmission and distribution.

One key opportunity DOE's Office of Science is pursuing is a new approach combining theory and synthesis of nanostructured materials, which have been identified as key to enabling the design of radically improved electrode architectures for superior power and energy densities and increased lifetimes of energy storage systems.

An essential part of this integrated research activity is the development of methods of analysis that will help elucidate structure activity relationships that serve as the underpinning for predictive model development and validation. Basic research will provide proof of novel concepts, which will lead to module level applied research for successful approaches. Introduction of promising concepts to industry will enable advances in manufacturing, cost and commercial perspective to continued development of commercially viable EES technologies.

CONCLUSION

Portable electronic devices, which are enabled by batteries, a form of energy storage, are now ubiquitous throughout society. When considering how widely accepted these devices have become in a relatively short period of time, one can imagine the potential inherent in storing energy at a much larger scale. Energy storage has the capability to reshape the way we fuel our cars, power our homes, and impact our Nation's economic future. Federal investment in the research, development, and deployment of energy storage technologies in combination with innovative policies and infrastructure investment, has the potential to improve grid performance, reduce our dependence on oil, and promote our energy security, economic competitiveness, and environmental well-being. I am privileged to contribute to these research efforts and thank you for the opportunity to testify today.

This concludes my statement, Mr. Chairman. I look forward to answering any questions you and your colleagues may have.