Energy Storage and America's New Energy Economy

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NEXT GENERATION ENERGY STORAGE

Introduction

Jay Inslee
Member of Congress

"Building a clean and economically beneficial energy system in our country will require the most innovative energy storage technologies possible."

"I'm pleased to introduce you to some of the most thoughtful and dynamic players in today's emerging clean energy era. Their vision and views, like mine, are focused on America's clean-energy future. And that future – which must start now – will create economic value and jobs, enhance our national security and protect the environment.

As the following pages and practitioners show, building a clean and economically beneficial energy system in our country will require the most innovative energy storage technologies possible. Many of these technologies are currently available, and some are still in the R&D phase. But each one deserves serious consideration and, going forward, they probably should be used in combination for the best results.

Private capital has been an enormous catalyst in driving the energy storage revolution thus far. But government can – and must – join in and play a powerful role in the advancement of these critical technologies if America is to reach its clean-energy goals in the transportation, manufacturing and utilities sectors of the economy.

The public sector is already doing its part, offering fiscally responsible loan guarantees and funding programs designed to help encourage energy-storage innovation take root in the marketplace and take hold in our lives.

Where appropriate and when necessary, other government tools must be developed and implemented to bolster and boost our progress in energy storage – including R&D investment tax credits, additional infrastructure investments, national net-metering and interconnection standards, meaningful renewable electricity standards, incentives for fuel-efficient vehicles, and workable market-based carbon limits, such as the one found in the American Clean Energy Security Act that was passed in the U.S. House of Representatives this year.

The world is changing rapidly, and after generations of fixating on energy supply – finding ever-increasing amounts of fossil fuels to stimulate our economy – we are now focusing on efficiently managing energy demand.

That's where energy storage comes in, and where energy storage becomes central to our nation's new energy economy. I encourage you to read on to learn more about how we can work together to make this bold idea a constructive reality."

Thought Leaders

Jesse Berst
Founder and Chairman
Global Smart Energy

"The grid has the huge challenge of precisely matching supply to demand on a second-by-second basis. Why? Because we have no economical way to store electricity at this scale."

Why is energy storage so essential to the New Energy Economy?
"Most of our big energy problems today are related to the difficulty we have in storing energy. Right now, we need to spend nearly $1 trillion to upgrade our grid. That grid has the huge challenge of precisely matching supply to demand on a second-by-second basis. Why? Because we have no economical way to store electricity at the grid scale.

Our medium-sized problems, such as the desire to electrify our cars, could also benefit from energy storage solutions. But unfortunately the batteries to make that technically feasible today are heavy and expensive, preventing us from achieving freedom from foreign oil.

Our small problems, such as our desire to be free of a wall socket tether when operating our electronic devices, would also be helped by better energy storage. Imagine how our work – and play – lives would change if we could carry a week's worth of power for all our gadgets in one pocket."

What is the most important use or implementation of energy storage?
"There are two closely intertwined answers. First, to create giant 'batteries' to absorb the energy from fluctuating and intermittent renewables such as wind, solar and marine energy. Second, to electrify our transportation – which only becomes sustainable if we can fully exploit renewables without bringing down the grid."

Which energy storage innovation do you most believe in?
"Thermal storage. If you think about it, the nation already has an enormous 'battery' in place in the form of our electric water heaters. They can be 'charged,' or pre-heated, in the middle of the night when the wind is blowing; and then they can be 'discharged' – or used – as needed. Likewise, we are discovering better ways to store the thermal energy from solar farms so they can produce power for hours after the sun has gone down, simply by tapping the stored heat."

Based in Seattle, Global Smart Energy is the world's leading authority on the electricity smart grid and the publisher of SmartGridNews.com.

Michael Butler
Chairman and CEO
Cascadia Capital

"We need to look beyond batteries, to a combination of available and efficient next-generation energy storage technologies that can help us reach our commercial and environmental goals"

Why is energy storage so essential to the New Energy Economy?
"A sweeping transportation transformation is under way in the energy storage sector, and it must go much further and faster if we are to protect America's national, economic and environmental security. At the epicenter of this commercial earthquake, however, are cutting-edge batteries and energy storage technologies. Without them, we run the risk of remaining stuck in the petroleum era – a dangerous place for a nation that aspires to long-term prosperity in the 21st century."

What is the most important use or implementation of energy storage?
"Very few storage technologies have actually reached the scalable commercial deployment phase, so we're not fully aware of the portfolio of possibilities – and the market isn't feeling the true impact of these innovations yet. Several companies produce lithium-ion batteries, for example, but utilities have only begun to experiment with them for balancing loads or storing power. And General Electric just jumped into the market for sodium batteries. These are computer-sized batteries that can store large amounts of power at wind farms.

The real issue, though, is that huge battery market growth – driven by hybrid vehicles and renewable energy – will need to be paced by improved battery performance. It's also important to note that advanced battery-centric solutions may not be able to deliver on their full promise and potential. So, we also need to look beyond batteries, to a combination of available and efficient next-generation energy storage technologies that can help us reach our commercial and environmental goals."

Which energy storage innovation do you most believe in?
"What really inspires me is the wide range of advanced battery innovation that's taking place at universities from coast to coast. Scientists at MIT, for instance, have developed a battery technology that may soon allow people to charge their cell phones in several seconds or a drained plug-in car battery in only a few minutes. These next-stage ultrafast charging batteries could also help electric cars accelerate and quickly stabilize the electricity grid, absorbing or releasing power to smooth out supply and demand fluctuations. And, because the MIT technology is based on an existing type of battery, it might be able to reach the commercial marketplace faster than one made of a different material."

Cascadia Capital, LLC is a national investment banking firm that is financing the future for sustainable industries, technology and middle-market companies.

Rick Luebbe
CEO
EnerG2

"To date, the energy industry has labored under a model where large-scale energy storage is difficult and costly. That model is broken and is in the process of being fixed – to everyone's benefit."

Why is energy storage so essential to the New Energy Economy?
"Energy storage is essential because the efficiency and sustainability of the New Energy Economy is in absolute jeopardy without it. So many of the generation and capture technologies that are emerging and evolving will depend on storage to make them effective and, in some cases, viable. In addition, energy efficiency is a key element of the energy gains that have become an expected part of our collective future. Energy storage helps to synchronize energy supply and demand, which is an essential first step in achieving global-scale gains in energy efficiency."

What is the most important use or implementation of energy storage?
"Breakthrough clean energy and efficiency technologies will help pave the way for our nation's economic recovery and the world's environmental sustainability. There is no innovation-oriented market with brighter prospects – or greater sweep or scope – than energy storage. It's nearly impossible to pick a single use of energy storage that rises above the others; rather, it's the universality of the need for better energy storage that defines its role in our economy. To date, the energy industry has labored under a model where large-scale energy storage – when it's even possible – is difficult and costly and usually implemented in the form of vessels of fossil fuel or chemicals. That model is broken and is in the process of being fixed – to everyone's benefit."

Which energy storage innovation do you most believe in?
"So far, the bulk of the energy storage conversation has revolved around ongoing advancements in battery technologies. But just as the overall energy industry is becoming more complex and multi-faceted, energy storage cannot be limited to a single technology. It will be a variety of technologies that ultimately solves the problem. In fact, I believe that it will be the interaction and combination of various storage technologies that will ultimately drive the innovation and advancements that the New Energy Economy requires.

Batteries are well understood and virtually ubiquitous. Nonetheless, ultracapacitors, a powerful alternative to batteries, are being increasingly embraced by the automotive industry for hybrid electric vehicles; by electronics and power-tool manufacturers for enhancing the life and usability of consumer goods; and by a variety of industrial customers to deliver an ever-increasing breadth of applications and technologies that improve energy efficiency. Any application that performs better or lasts longer using rapid charge and discharge cycles will benefit from ultracapacitor-based energy storage systems. In one particularly interesting example, electric-rail operators in Europe are adopting ultracapacitors to capture the kinetic braking energy created by trains approaching a station. They're then using that captured energy to power departure and initial acceleration of that or another train. The energy efficiency gains of this relatively simply application have been enormous. If we can find ways to meld batteries and ultracapacitors in new and unprecedented combinations, I believe we'll double our chances for sustainable success in a variety of key industries while, at the same time, boosting both our energy and economic futures."

EnerG2 is focused on introducing advanced nano-structured materials for next-generation energy storage breakthroughs.

Mark McGough
President and CEO
Pentadyne Power Corporation

"Stored energy – whether in the form of lead acid batteries or the more reliable flywheel systems – keeps hospitals running, data centers functioning, call centers responding, and other businesses on line."

Why is energy storage so essential to the New Energy Economy?
"Despite recent economic conditions, electric energy use continues to grow by leaps and bounds. This makes viable energy storage more and more important on both sides of the utility fence. That means large-scale grid energy storage to better load-balance day/night, energy storage as a buffer to the grid in wind turbine apps, and, of course, on the customer side to protect critical loads for power quality issues on the utility grid."

What is the most important use or implementation of energy storage?
"Backup power systems using stored energy during power outages are a critical application for American industry. Stored energy – whether in the form of lead acid batteries or the more reliable, but more recent to the market, flywheel systems – keeps hospitals running, data centers functioning, call centers responding, and a host of other businesses on line no matter what. Stored energy systems solve an estimated $100 billion problem for American industry by ensuring that critical businesses and processes run 7x24.

Also, large-scale energy storage – like pumped hydro or other relatively clean implementations – would make the most difference to the utilities. But to utility customers, and our customers, clean, affordable and reliable energy storage is critical at data centers, hospitals, manufacturing facilities, labs, universities and virtually every large corporate entity that has its own data facility. While there's been cheap battery-backup energy storage for decades, it has proven to be relatively unreliable, fragile, costly in the long run and disturbingly hazardous."

Which energy storage innovation do you most believe in?
"Pentadyne flywheels of course! Not only are flywheels as a class the most reliable for backup power apps, but our unique design eliminates the least reliable components of legacy designs – namely the bearings. We use magnetic, non-contact bearings that do not fail like mechanical bearings. In addition, Pentadyne offers the market the only technology that turns subway trains into true hybrid electric vehicles!"

Pentadyne Power Corporation designs, manufactures and markets advanced flywheel energy storage systems that provide ride-through power and voltage stabilization for power quality and power recycling applications. Pentadyne is the world's leading manufacturer of flywheel energy storage systems.

Terry Murphy
President
SolarReserve

"Molten salt power towers have inherent thermal energy storage that allows utilities to meet future demand without having to expend additional capital resources in spinning reserves."

Why is energy storage so essential to the New Energy Economy?
"The bottom line is that the utilities need predictable, firm power; and storage gives them that capability."

What is the most important use or implementation of energy storage?
"The question shouldn't be about meeting RPS targets, the question should be whether we're beginning to replace fossil fuel requirements with renewables. Molten salt power towers have inherent thermal energy storage that allows the utilities to meet future demand without having to expend additional capital resources in spinning reserves."

Which energy storage innovation do you most believe in?
"Well, I may be a little biased, but a SolarReserve molten salt power tower converts the suns thermal energy into 1050F molten salt with 88% efficiency; that's hard to beat. The SolarReserve configuration captures and focuses the sun's thermal energy with thousands of tracking mirrors called heliostats to a central receiver on a 600-foot tower. Within the receiver, the concentrated sunlight heats molten salt to over 1,000 degrees Fahrenheit. The heated molten salt then flows into a thermal storage tank where it is stored until the utility needs the power; then, on demand, it's pumped to a steam generator to drive a standard turbine to generate electricity. This process, also known as the 'Rankine Cycle,' is similar to a standard coal-fired power plant, except it is fueled by clean and free solar energy. Other than the few unique components, our power plants are comprised of available materials, such as mirrors, and established technologies, such as steam generators and turbines. This will enable us to provide emission free electricity at competitive prices and protect the ratepayer from the market volatility of fossil fuel."

Backed by a strong portfolio of top-tier financial firms and supported by an exclusive worldwide license from United Technologies, SolarReserve builds utility-scale solar power plants to deliver clean and renewable energy.

Kirk Washington
General Partner
Yaletown Venture Partners

"We need more super capacitors because of their high power density (ideal for hybrid vehicles), and flow batteries because of their potential for mass energy storage."

Why is energy storage so essential to the New Energy Economy?
"The core issue is that we need to get smarter about how energy is use. We can no longer afford, and just don't have enough, to waste; so efficient and cost-effective storage can be a key technology, especially for managing solar and wind assets. A gust of wind, or a partly cloudy day, can wreak havoc on a utility grid with significant renewable assets installed and cause power surges and sags. Energy storage can smooth the peaks and valleys and help balance supply and demand. It's kind of like a buffer."

What is the most important use or implementation of energy storage?
"I'm particularly interested in auxiliary power units for vehicles. That means boats anchored in harbors, trucks idling overnight at rest stops and, one day, passenger cars. They are wasting fuel and sending unnecessary emissions into the air. We have hybrid auxiliary power units for trucks, but the real goal is all electric or battery-powered versions. This is practical energy storage, and it's needed."

Which energy storage innovation do you most believe in?
"When I think about energy storage, the solutions that make the most sense today, and are worth considering, are where the amount saved from eliminating system waste far exceeds the cost. Specifically, I think we need more super capacitors because of their high power density (ideal for hybrid vehicles), and flow batteries because of their potential for mass energy storage (utility scale, like for wind and solar)."

Based in Vancouver, Yaletown Venture Partners leverages an extensive on-the-ground network to seek out the most promising clean technology and IT investment opportunities in Canada and the United States.

Jill Watz
Senior Advisor
Vulcan Capital

"Advances in materials science provide new and novel processes and materials to improve energy density and specific energy storage devices."

Why is energy storage so essential to the New Energy Economy?
"The New Energy Economy will transform our energy system to a low-carbon state for both electricity and transportation. This requires a large-scale penetration of low-carbon electricity and an electric transportation system that depends on a new electric grid system that is flexible, dynamic, self-healing, highly reliable and distributed. Energy storage is essential to achieving all of this functionality. At the system level, large-scale storage enables greater penetration of intermittent renewables like solar and wind, and it helps improve system robustness. At the distribution level, storage enables improved power quality to protect increasingly sensitive loads from voltage sags and transients, and enables greater penetration of distributed energy to directly serve load without costly transmission. Lower cost, as well as reliable and robust on-board storage, is critical to the expansion of electric vehicles, which will greatly increase the efficiency of our transportation sector."

What is the most important use or implementation of energy storage?
"Just as there is no single technology solution to solve the climate change problem, energy storage technologies vary by type, scale, application and location. Large-scale physical storage, like pumped hydro or compressed air energy storage (CAES), are proven technologies with well-defined costs, but they are geographically limited. Evaluating traditional large-scale hydro for its potential for firming intermittent power In the Pacific Northwest and other hydro regions is another important opportunity for bulk energy storage, and it could reduce the average cost of power for large-scale renewable penetration in those regions.

Storage plays an important role in improving the efficiency of electricity markets by enabling a more active demand side as well as greater distributed resources. For too long, investments have been skewed disproportionately to the supply side, leaving the demand side relatively inactive and creating market distortions. For example, distributed energy storage in electric vehicles can be aggregated through smart controllers to provide ancillary services to the power system and help reduce electricity costs. Similarly, energy storage devices, coupled with consumer-distributed generation, will enable more local, clean-energy production and reduce expensive new transmission infrastructure requirements."

Which energy storage innovation do you most believe in?
"There are promising new technologies under development to meet storage capabilities at all levels. Advances in materials science provide new and novel processes and materials to improve energy density and specific energy storage devices. I think there is great promise in the application of nanostructures to create super ultracapacitors for large-scale energy storage in vehicles, and to enhance the electrode capacity in more conventional battery chemistries to reduce costs and improve cycle life."

Vulcan Capital is a leading private investment firm that creates long-term value by applying extensive industry knowledge, operational expertise and flexible financial resources to attractive investment opportunities.

Conclusion

Ahmad Pesaran
Principal Engineer
National Renewable Energy Laboratory

Ahmad Pesaran has been involved in energy storage for energy efficiency and renewable energy applications in various sectors for many years. As a senior researcher at the National Renewable Energy Laboratory (NREL), the nation's primary R&D laboratory for renewable energy and energy efficiency, Pesaran has developed impressive capabilities at NREL, depth, and expertise that have helped him understand emerging storage technologies and how they can best contribute to the New Energy Economy. Here, in our final installment, Pesaran applies his uniquely positioned perspective to the possibilities, problems and potential of energy storage

Why is energy storage so essential to the New Energy Economy?
"I believe that the New Energy Economy must consist of renewable energy and energy efficiency in all sectors of the energy consumption market, including buildings, transportation, and industry. Energy storage is a major and vital component of the green technologies needed in this new economy.

In the transportation sector, hybridization and electrification of vehicles increase energy efficiency and fuel economy, thus reducing oil consumption. Hybridization of vehicles with electric energy storage allows significant fuel efficiency increases by using regenerative braking, permitting vengine downsizing, engine load leveling, electrifying accessories, and reducing fuel use during stops. In addition, plug-in hybrids and all-electric vehicles allow a significant amount of fuel to be replaced with electricity, reducing the nation's dependence on imported oil and saving U.S. consumers millions of dollars that they would otherwise spend on fuel. Energy storage devices such as batteries and ultracapacitors are the enabling components that make hybridization and electrification possible.

Just as important, the electricity needed for the building, transportation, and industrial sectors could be generated through renewable energy technologies such as wind systems and solar photovoltaics (PV). These renewable energy technologies, major components of the New Energy Economy, could produce significant amounts of clean, renewable electricity and reduce polluting emissions, improve air quality, and positively impact climate change. To generate significant electricity from wind and PV, we must address one of their major drawbacks: intermittency. The fact that these resources are not always available limits their penetration into electricity markets. This limitation can be addressed by adding an energy storage system.

Previous studies have indicated that traditional electric power systems are inherently limited in their ability to accept very large amounts of PV or wind energy because of their intermittency. For example, a large fraction of wind or PV electricity generation occurs when electricity demand is relatively low. In addition, the existence of large, inflexible thermal steam plants (powered by coal or nuclear) results in a significant portion of wind- or PV-generated electricity that must be "spilled" or shed, rendering that shed energy unusable. This results in increased costs per unit of energy or power. At some point, when wind or PV is supplying from 10% to 20% of a system's energy, the cost penalties and diminishing returns of increasing wind or PV generation will likely limit the economic use of these generation technologies. To increase the market penetration of PV and wind beyond 20% of the grid's capacity, other approaches are needed to enhance the usefulness of renewable electricity generation.

"Electric energy storage is thus an important technology that is essential for the New Energy Economy. "

Analyses by NREL and others have shown that, among various possible approaches, energy storage provides the ultimate solution by allowing excess PV or wind generation to be stored and delivered at a later time. Integrating electric energy storage with PV and wind generation has the potential to blur the line between intermittent and baseload generation technologies.

Electric energy storage is thus an important technology that is essential for the New Energy Economy. First, it makes vehicles more energy efficient and provides them with the ability to switch to renewable electricity as a transportation fuel; second, it increases the market penetration of PV and wind electricity generation by addressing the intermittency barrier."

What is the most important use or implementation of energy storage?
"The most important use of energy storage is for the generation and use of green electricity in virtually all sectors of the economy. We have noted how energy storage in hybrid and other electric vehicles can significantly reduce our dependence on oil (particularly from foreign sources), reduce emissions, and positively impact climate change. Electric energy storage must also be implemented in solar PV and wind power plants so that excess electricity can be stored for later use and allow greater market penetration of renewable sources into the electricity grid. This type of energy storage can be implemented in a centralized system consisting of megawatt-size units or in many smaller energy storage systems distributed throughout the grid.

Energy storage devices can also be used in the building and industrial sectors to store electric energy locally for immediate, same-day or later use. For example, a large energy storage system with a high power-to-energy ratio could be deployed to hybridize a power plant and provide frequency regulation; in the process, this would provide spin reserve and/or standby reserve services. In addition, energy storage systems could be deployed near neighborhood substations or even in residential buildings, to store electricity for later use during peak demand times to prevent brown-outs.

In summary, energy storage will be needed and used in the New Energy Economy in gasoline and fuel-cell hybrid electric vehicles, plug-in hybrid vehicles, all-electric vehicles, PV and wind electric power plants, conventional power plants, substations and buildings."

"The synergy between the energy storage devices used in vehicles and the ones used for renewable grid applications is strongest when batteries and ultracapacitors are used for both."

Which energy storage innovation do you most believe in?
"There are several options for energy storage: batteries, ultracapacitors, flywheels, compressed air, pumped hydro, flow batteries, and superconducting magnetic energy storage or SMES. Each has advantages and disadvantages for different applications in transportation and stationary/grid applications. There are also many chemistry choices for batteries, such as lead acid, sodium sulfur, and lithium. Initial capital cost and life dictate the choice of energy storage for stationary applications, so $/Wh/cycle is an important selection parameter. For transportation applications, in addition to cost and life, vehicle manufacturers pay close attention to mass, volume, and safety. Connecting the energy storage system in plug-in and electric vehicles to the electricity grid using bidirectional lines will enable their use as distributed energy storage systems for ancillary services, commonly referred to as the vehicle-to-grid or V2G concept.

For vehicle applications, I believe only lithium batteries will be competitive in the New Energy Economy because of the tremendous advantages they possess in full hybrid as well as plug-in and electric vehicles. Ultracapacitors can play a significant role in mild and start-stop hybrid markets; there could even be considerable potential for using ultracapacitors in conjunction with batteries for plug-in and electric vehicles if there is a significant decline in the cost of the power electronics needed to integrate the two systems. The synergy between the energy storage devices used in vehicles and the ones used for renewable grid applications is strongest when batteries and ultracapacitors are used for both. This dual use of batteries and ultracapacitors in transportation and utility applications will increase the demand and volume for lithium batteries and ultracapacitors. As high-volume production facilities are built, costs will drop and increase the market penetration of these two energy storage technologies. Therefore, we look forward to a lot of innovation in lithium battery and ultracapacitor technologies."

The National Renewable Energy Laboratory (NREL) is the nation's primary laboratory for renewable energy and energy efficiency research and development (R&D) An employee of the Alliance for Sustainable Energy, LLC, (Alliance) under Contract No. DE-AC3608G028308 with the U.S. Department of Energy has authored this document. The views and opinions of the author expressed herein do not necessarily state or reflect those of Alliance or the United States Government and shall not be used for advertising or product endorsement purposes.

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