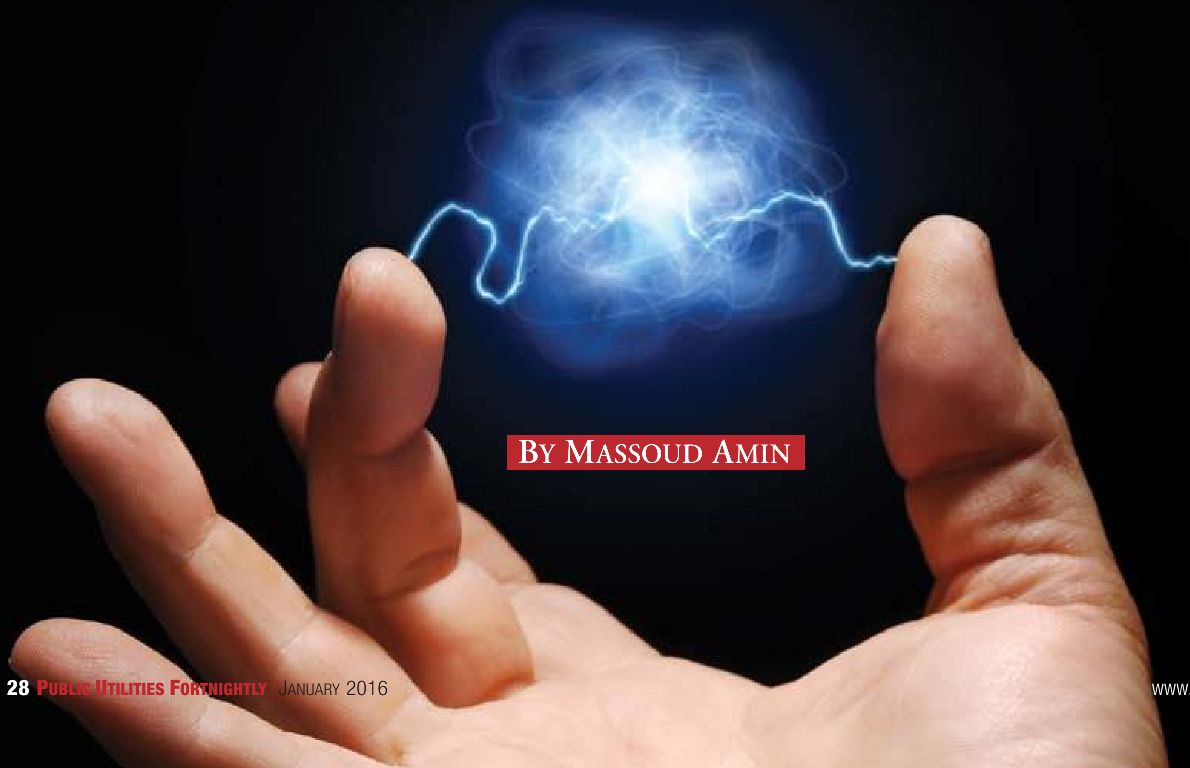
Microgrids & Battery Storage

In search of enlightened policy to build a solid business case.



By Massoud Amin

Skeptics occasionally describe a new technology as a solution in search of a problem. But in the case of microgrids, and of battery energy storage (BES) at the edge of the distribution grid, we have technically sound solutions to well-identified problems. The "search," if you will, ought now to focus on a positive business case, bolstered by sound policy. Yet it remains a complex task to create a positive business case, which is further complicated by outdated policies at the federal, state and local levels.

Technology, policy and standards must coalesce to produce value in this scenario, as with most smart grid-related implementations. Energy, communications, power electronics, and computing represent only a few of the technology elements that must be integrated to create a BES-assisted microgrid.

Financially successful, BES-assisted microgrid implementations depend on a complex matrix of factors that create multiple value streams. And that matrix will change, depending on whether microgrid ownership belongs to a utility, an end-customer, is shared between them, or belongs to a third party.

Yet current and planned microgrids, demonstration projects, market forecasts, and industry surveys all suggest that BES-assisted microgrids will proliferate going forward. And that leads to new questions: Where? When? How? The new energy frontier, which includes BES-assisted microgrids, is rife with uncertainties. Some of these uncertainties are technological, but most pertain to business models and the outdated policies that hinder investment.

In articles I authored for *Public Utilities Fortnightly* earlier this year – "The Case for Smart Grid" (March 2015, p. 24) and "Securing the Smart Grid," (April 2015, p. 14) – I described the drivers, goals and security concerns that accompany grid modernization. Those articles set the stage for a more focused look at the specific drivers, goals and hurdles affecting the successful implementation of BES-assisted microgrids. Let's now consider use cases, value propositions, and the evolution of policy at the federal, state, and local level that affect the fate of these technologies and their successful implementation.

Microgrids: Up and Downstream

For a utility, a microgrid can provide an ideal platform for realizing the smart grid benefits of increased reliability, renewable energy integration, diversification of energy sources, and flexible demand response. For end customers, a microgrid can provide some of the same benefits, as well as islanding and power continuity when the central grid fails. And here the term "end-use customer" can include a commercial and industrial entity or a hospital, campus or community. Energy service companies (ESCOs), meanwhile can also play an ownership role by financing and operating a microgrid for a client and splitting the benefits. Of course, which player owns, operates and controls a microgrid affects how the business case is shaped and how costs and benefits are weighed. Therefore, generalizations on the complexities of a positive business case should be viewed skeptically.

If federal and state policies must change to enable a positive business case for microgrids, then so be it.

Small commercial and industrial (C&I) customers bear the biggest cost for short-term power outages, so theoretically they will benefit most from BES-assisted microgrids. The combination of rooftop solar, BES and microgrids boosts the business case for small C&I customers, as it allows a reduction in peak demand and therefore lowers demand charges. If and when a cap-and-trade system for carbon emissions is adopted, the combination of solar and a BES-assisted microgrid will reduce GHGs and provide even greater value to the microgrid owner. But the far greater number of residential premises will also benefit from a home-based energy management system, with energy storage, that will resemble a microgrid. This arrangement is often called a nanogrid. The value of reliable, resilient, and secure power to a home or business owner, in an increasingly digital era where security and privacy are essential, is that it relies on consistent, quality power enhanced by energy storage.

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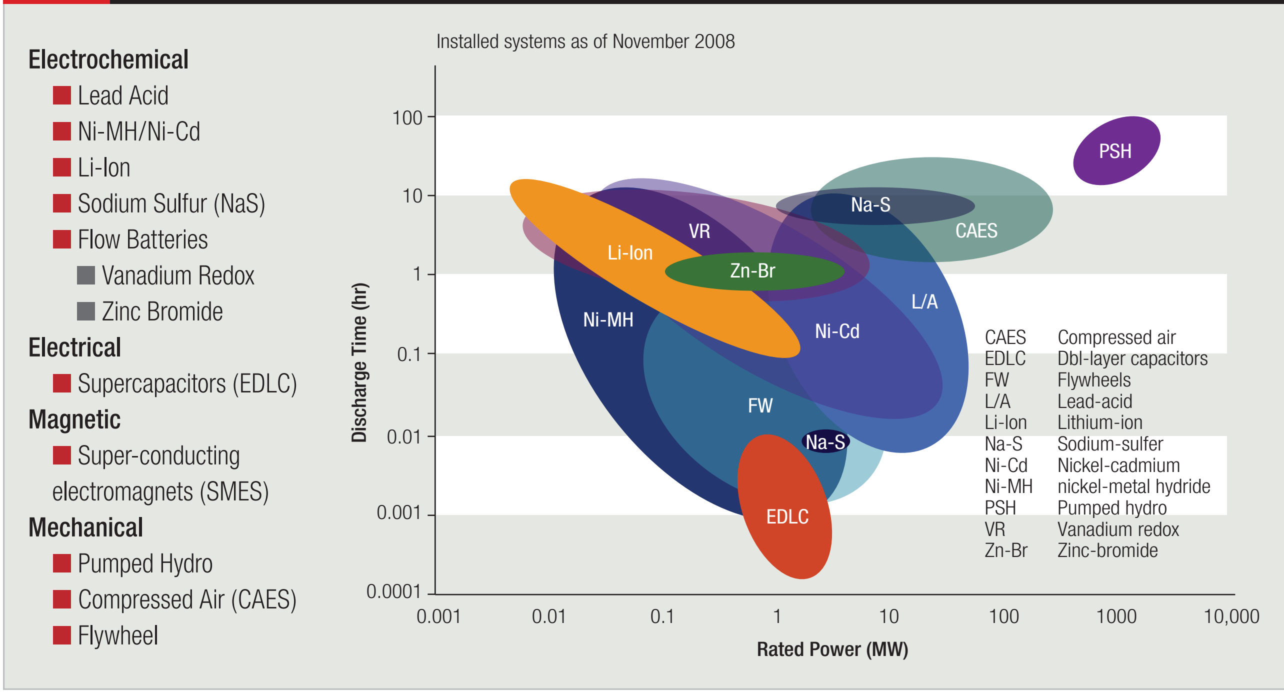
Battery Storage: Microgrids and Beyond

Battery energy storage remains a key component of microgrid

FIG. 1 **TECHNOLOGIES**



Source: Electricity Storage Association, www.electricitystorage.org

strategy, as it enables the time-shifting of energy. It helps the microgrid – whether utility-, customer- or third-party-owned, grid-connected or islanded – to balance generation and load, integrate intermittent renewables, and provide an opportunity for earning revenue from energy arbitrage.

The context for BES-assisted microgrids is that electrochemical a.k.a. battery storage also has uses on the distribution system as distributed energy storage systems (DESS) and as customer-premise energy storage systems (ESS). The latter can even come from one or more electric vehicle batteries. Somewhere in between, depending on how it functions, is community energy storage (CES). Any and all of these roles could (and should) be integrated with the grid and they may impact a microgrid's operation. To achieve strategic value from smart grid investments, in the new energy frontier, every node on the network must become a smart, secure, efficient, energy node.

Operational use cases for battery storage generally fall into four categories:

- Utility controlled for distribution system benefits
- Utility controlled for distribution and market benefits
- Shared utility-customer control for bill savings and market revenue
- Customer controlled for customer savings

Public-private cooperation among stakeholders is needed to fairly analyze the costs and benefits of BES in microgrids and elsewhere, and determine the value chain and who pays and who benefits. Determining the value propositions and value chains for BES for all stakeholders will not only help formulate a microgrid business case, it will also help us determine whether to invest in enhancing existing storage technologies or inventing new ones. Models that simulate the role and demonstrate the costs and benefits of BES for various stakeholders will help determine its optimal uses: from generation to transmission to distribution to the end customer and for microgrids. In fact, this is one of the components of research we are currently doing at the University of Minnesota.

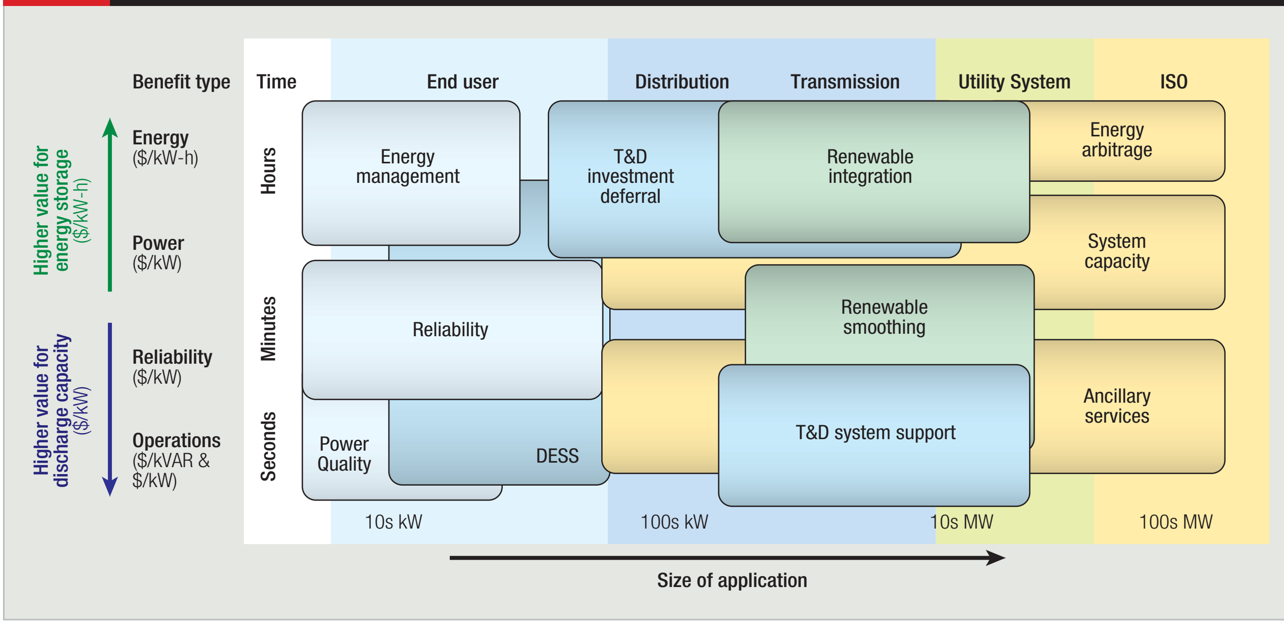
Utilities are rightly concerned over safety, but undue delay in granting interconnection rights to microgrid developers will promote market uncertainty.

Work at Univ. of Minnesota

The strategic goal of our research at the University of Minnesota is to enable more secure, resilient, and smarter critical infrastructures. To achieve that, we aim to understand the true fundamental dynamics of complex, interdependent networks that integrate energy, communications, transportation, and economics to enable more reliable, resilient, sustainable, and more secure power grids.

We develop and apply analytical and multi-domain modeling, simulation and testing methodologies to assess the effects of smart grid technologies on distribution system operations and performance, including microgrids applicable to military bases operated by the U.S. Department of Defense. Our results integrate aspects of cyber-physical security, dynamic price and demand response, the mix and placement of storage devices, and the integration

FIG. 2 **USE CASES**



Source: Electricity Energy Storage Technology Options--A White Paper Primer on Applications, Costs and Benefits, EPRI, Palo Alto, CA, 2010, Report #1020676

of wind, solar, and intermittent distributed energy resources, as those elements are combined with sensing, communications, and dynamic optimization and reconfiguration. Applying this comprehensive systems approach, performance results for several distribution system test cases have been performed.

With respect to microgrids and BES, for instance, we are trying to determine the value of energy storage systems from an end-use perspective by performing optimization modeling and simulations for energy storage technology comparisons. This effort includes load forecasting and assessing trade-offs in face of emerging trends, as noted in my earlier *Fortnightly* publications in March-April 2015. It also includes the operation of and planning for BES-supported microgrids, customer-premise energy storage systems (ESS), and distributed energy storage systems (DESS). In particular, pertinent projects include the following:

Distribution Systems. Self-organizing microgrids with integration and optimization of storage devices and plug-in hybrid electric vehicles with the electric power grid. Assessments performed on several IEEE test cases as well as on the UM-Morris Campus, combined with practical costs, risk and reliability analyses.

End-to-End Systems. (*I.e.*, power generation, transmission, and distribution systems, as overlaid with communication networks and markets.) This category includes a) fast power grid simulation and risk assessment (a 12-to-15-fold speedup in dynamic risk assessment), and b) distributed state estimation and implementation of smart software agents, such as a distributed computer.

Cyber-physical Security. The objective of this cluster of projects is to model, design and develop reconfigurable and distributed smart energy systems supported by secure sensing/wireless communication network overlay and fault-resilient real-time controls. Projects include: a) security of cyber-physical infrastructure and development of resilient real-time systems for a secure and reconfigurable end-to-end power system; and b) security analyses of autonomous microgrids, including i) analysis, ii) modeling simulation of failure scenarios, and iii) development of Attack-Resistant Architectures.

Community Assessments. Due to the size, complexity, and cost of transforming the existing electrical grid to a smart self-healing system, the process will need to occur in several stages over time, with equipment replaced gradually as it reaches the end of its operating life. Focusing on smart grids for communities and at a college campus level, we find that university microgrid projects offer very practical environments for testing smart grid systems in particular communities. We employ a holistic systems approach for all of our work on this project. It engages faculty, postdocs, researchers, undergraduates, consumers from across the local community, as well as utilities from the wider smart grid coalition in Minnesota to build consensus on issues such as microgrid configuration, cost-effectiveness, and security.

FERC may reconsider interconnection policies for small generators to ensure a fair process. That's a good start, but there's more to be done.

For customer-premises energy storage systems (for both residential and C&I customer classes), our objectives are to reduce monthly energy charges, demand charges, and the costs

Fig. 3 **On-Site Options**

Application	Description	Requirements
Energy Management	Shifting load from high to low price periods, thereby reducing (daily) energy charges. For real-time or time-of-use rate structures.	kWh: medium kW: medium Cycles: high
Demand Management "peak shaving"	Reducing peak demand over a long period of time (typically one month).	kWh: medium kW: high Cycles: low
Reliability "emergency backup"	Supplying extended backup power to allow customer to ride through grid-side outage	kWh: high kW: medium/high Cycles: low
Power Quality	Filtering voltage spikes/sags, noise and other transient events. Ability to ride through momentary outages (< 1 min). (*i.e.*, UPS)	kWh: medium kW: medium Cycles: low
Utility Services	Provide load control, reactive power support, voltage regulation or other services to the local utility	kWh: varies kW: varies Cycles: varies

of outages – objectives that face technical constraints related to battery operations and cycling. Thus, significant value lies in allowing a subset of high cost-of-outage customers – including small C&I customers with the most to lose from short power outages – to ride through an outage with help from ESS. As stated earlier, this arrangement becomes markedly more valuable when combined with rooftop solar generation. With time, such an end-customer energy management system may come to resemble a BES-assisted microgrid.

Federal Policy Needs Tweaking

In June of last year I testified before the U.S. Federal Energy Regulatory Commission (FERC) on policies affecting the business case for smart grid, microgrids, and similar investments, which I described the challenges that lie before us:

"The challenge," I noted, "is to reduce uncertainties over what regulators will do next and what investors will do next."

And to support my view I quoted these added comments from Ms. Anne Pramaggiore, CEO for Commonwealth Edison: "Today's regulatory framework" she said, "is keeping us locked into the 20th century."

Some states employ a process that allows utilities to study the potential grid impacts of operating a private microgrid (not owned by a utility) that requires an approved interconnection with the grid. This situation leads to a perhaps unintended consequence: of allowing utilities to cause delays and undue costs for microgrid developers. Utilities are rightly concerned about the safety of interconnecting microgrids, and they understandably want time to grasp how a proliferation of microgrids might impact their business model. Yet we already know that privately owned and BES-supported microgrids have both upstream and downstream benefits (as well as costs), so any undue delay or cost to the non-utility microgrid developer – whether a C&I customer, a college campus or other community, or even an ESCO (energy service company) – will only promote market uncertainty and potentially inhibit such projects.

We need more federal R&D on battery energy storage technology, which has proven itself conceptually, but which must lower costs and improve performance to meet expectations.

At the federal level, FERC's small generator interconnection procedures (SGIP), adopted in 2005 under FERC Order 2006, cover distributed generation projects up to 20 megawatts in size and how they interconnect with interstate transmission systems. This rule is relevant to microgrid developers who wish to sell wholesale power into regional markets run by an independent system operator (ISO). FERC has issued a notice of proposed rule-making (NOPR) that it may amend its SGIP and small generator interconnection agreement (SGIA) policies to, in its words, "ensure the time and cost to process small generator interconnect requests will be just and reasonable and not unduly discriminatory." That's a good start. But there is more that can be done.

FERC and other federal agencies can work to resolve technical and jurisdictional issues associated with generation sources such as rooftop solar, microgrids, and battery energy storage that serve both distribution and transmission grids and that operate across

Fig. 4 **Costs & Policies**

- **Economic**: Higher price differences between on-peak and off-peak power due to congestion, limited capacity
- **Regulatory**: Federal Regulatory Energy Commission mandate to support fast-ramping regulation resources
- **Technological**: Investments in battery technology R&D for consumer and transportation applications
- **Regulatory/Economic**: 2007 U.S. Energy Storage Competiveness Act and ARRA Demonstration Grant
- And *many more* …

state regulatory boundaries. FERC and system operators should revise market designs to accommodate a high penetration of renewable resources.

On a strategic basis, increased federal research and development is needed for new technologies such as BES-supported microgrids and how they can benefit stakeholders both upstream and downstream. That should include BES technology, which has proven itself conceptually, but still needs to improve in performance and drop-in cost to meet expectations. Work is needed on increasing energy storage density and battery life, decreasing costs, and identifying secondary markets for used batteries. I have not delved here into the minutiae of the myriad of options regarding battery energy storage because, as with microgrids, proponents must mix and match these variables to suit local circumstances.

State Policy: Minnesota in Action

To examine state-level regulatory issues, it is convenient to turn to my home state of Minnesota, which has vigorously explored the barriers to microgrid development, given the potential value to the state's goals. Minnesota policymakers have determined that microgrids appear to align with their energy, environmental and economic policy goals, which emphasize energy assurance as a fundamental condition for prosperity and security. Minnesota's Clean Energy Economy report (October 2014) was a comprehensive effort to quantify the direct employment and wages of clean energy businesses and it analyzed five sectors (wind power, solar energy, bioenergy, energy efficiency and smart grid) and their value chains in 2000-2014. Smart grid, which included microgrids, was the top sector. The clean energy economy grew jobs at seven times the overall rate. That sector created $1 billion in wages in 2013, allowing Minnesota to be ranked 8th nationally that year in clean energy patent development.

Thus Minnesota, like many states, is reviewing its policies as it balances incumbent utility interests with ESCO competition and the needs of C&I and residential customers. A state-level, results-oriented regulatory approach that rewards utilities for paving the way for innovations that directly benefit their customers can encourage stakeholders to explore the microgrid business case with greater confidence and less uncertainty.

For enlightening reading in this area, I highly recommend David Malkin and Paul Centolella's insightful essay, "Results-Based Regulation: A More Dynamic Approach to Grid Modernization," which appeared in *Public Utilities Fortnightly* (March 2014, p. 28).

With access to resources on relevant technology and standards, regulatory reform and stakeholder impacts, state policymakers can shape policies that encourage microgrid project development and balance the diverse interests involved. Those policies must keep pace with relevant standards affecting microgrids assisted by battery energy storage.

In 2013, the Minnesota Department of Commerce published a white paper, "Minnesota Microgrids: Barriers, Opportunities, and Pathways Toward Energy Assurance," which offered a plan for tackling the issues. Briefly, that paper called for a review of policies affecting microgrids and a number of other efforts, including 1) identifying pertinent interconnection standards and practices, 2) researching and modeling of potential electric loads available for microgrid control, and 3) identifying affected stakeholders. The paper also called for identifying renewable resources accessible for microgrid-based integration and examining the economic and operational factors involved with microgrids based on renewable energy. Finally, Minnesota's white paper recommended policies that support microgrid benefits for ordinary Minnesotans.

Work is needed on increasing energy storage density and battery life, decreasing costs, and identifying secondary markets for used batteries.

One important step in Minnesota's forward-looking plans is the establishment of a multi-stakeholder pilot project that can serve as a test-bed to address various technical and safety issues, as well as determine the various costs and benefits and how they can be assigned to the various players in a manner that supports a positive business case for the microgrid sponsor, whoever that turns out to be.

In addition to these microgrid-related activities, legislation has been introduced (though not yet passed) to a establish a "Made in Minnesota Energy Storage System Rebate Program" that would rebate up to half the cost of installing locally made energy storage technologies by either a utility or customer.

I am aware that California also is taking many creative steps towards similar goals, but I am better versed on Minnesota's

Fig. 5 **Take-Aways**

- Storage system benefits should be analyzed from a utility as well as a customer perspective
- Customer-premises energy storage
- Multi-application systems have greater value
- Practical methods are needed to prevent excessive cycling and sel-back
- Cost still inhibits practicality for most commercial settings
- Priority ride-through
- Not all loads are created equally
- Priority ride-through conserves critical backup resources, but requires implementation of distributed, high-speed load shedding
- Intentionally islanding sub-networks/microgrids can provide significant value to local customers with payback period of almost one year!
- Marginal benefits to utility through increased reliability

progress in these areas. Still, California can be thought of as another early adopter state whose legislative and regulatory efforts deserve scrutiny and may well serve as a role model for others states considering similar steps.

While not directly connected to the foregoing projects, my fellow Minnesotans and I also are building a Minnesota Smart Grid Coalition to assess technologies, business cases, regulatory models and education and training opportunities, among a long list of initiatives. We are identifying potential smart grid pilot and demonstration projects, developing multi-stakeholder operations, forming business and regulatory models, and creating a "smart grid sandbox" at the University of Minnesota where vendors can donate technology for our testing and integration work. All of these efforts will enable us to accomplish another important goal: to create a "Smart Grid University" for the education and training of the next-generation of thought leaders, engineers and economists who will implement what we learn through our collective efforts.

The Road Ahead

The new energy landscape is changing, and swiftly. We need to work in concert with all stakeholders to enable the safe, reliable implementation of any and all technologies, markets and practices that will support sustainable, affordable power to drive our economy and, therefore, our security. Consumer engagement will be critical to successful policy development and implementation to enable grid modernization from end to end.

Microgrids supported by battery energy storage will play a critical role in the proliferation of distributed energy resources at the grid's edge, which can benefit a wide array of stakeholders, including consumers.

Yet if the power industry does not move swiftly and adroitly to engage consumers, we run the risk that disruptive forces will prevail. The goal, as in any business, should be to deliver value to the customer. But if federal and state policies must change to enable a positive business case for microgrids, then so be it.