PLANNING FOR

SAFER, BETTER, BIGGER BATTERY ENERGY STORAGE

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Large battery energy storage systems (BESSs) have reached a tipping point. Developments in technology, policy, energy supply and demand, and economics have combined to spur substantial growth for larger installations. This growth is heightening safety and performance concerns.

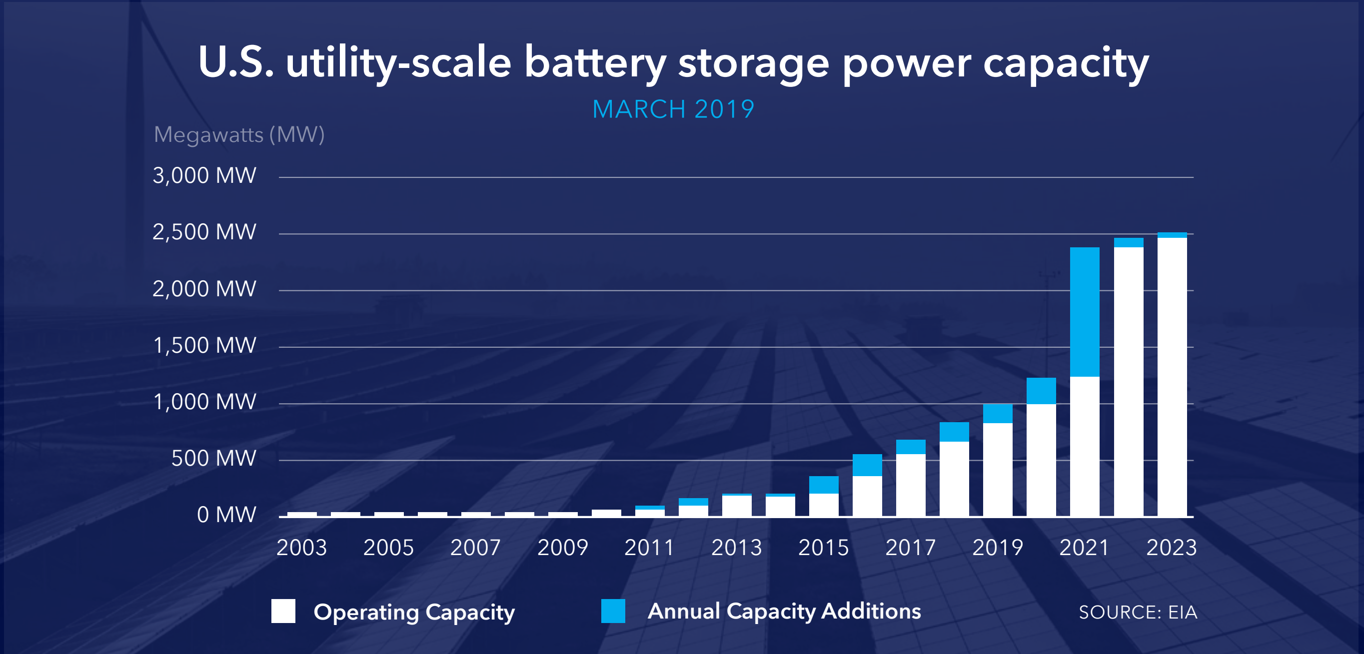
BESS fires can start at the cell level because of impact, overcharging or manufacturer defects. Safety systems are designed to mitigate thermal, electrical, and mechanical damage risks to cells. Fire risk increases with the number of cells in a system — and a utility-scale (1MW or greater) BESS typically contains tens of thousands of cells.

How can utilities, independent system operators (ISOs), distribution network operators (DNOs) regulators, battery manufacturers, large energy users, governments and emergency responders collaborate to ensure that utility-scale BESSs are safer and performing optimally? Also, how can the process of negotiating contracts for utility-scale BESSs bring all these players together for best outcomes?

In the five years preceding 2019, the utility-scale segment of the BESS market quadrupled to nearly 900 MW of total operating capacity in the United States – and that is expected to nearly triple again by 2023, to 2,500 MW or more.

Consequently, more than ever, North American utilities and energy retailers are acquiring large-capacity BESSs – either directly or in partnership with third parties. A recent Edison Electric Institute study listed more than 50 such BESS deployments. As a result of FERC Order 841, gigawatt-hours of energy storage projects will open across the U.S. starting late 2019.

Elsewhere across the world, China falls only slightly behind the U.S. in projected BESS growth. These two nations together account for 54% of total expected global BESS deployments by 2024. Countries in the second tier of BESS growth include Japan, Australia, South Korea, Germany, Canada, India and the U.K. Europe is poised to exceed the U.S. in battery production, which will likely improve the economics of BESS projects there.



The need for greater power system flexibility is a key driver of utility-scale lithium-ion (Li-ion) battery deployments, both grid-tied and behind-the-meter.

Through these deployments, network operators can:

- Accommodate more renewable energy.
- Provide ancillary power system services, especially frequency regulation.
- Ensure resource adequacy.
- Expand grid capacity (with stationary and sometimes mobile BESSs).
- Offer fast-response capacity to meet peak demand.

Large electricity customers in the commercial and industrial sector are installing their own BESSs behind the meter, usually to control demand charges. For instance, Ontario, Canada's Global Adjustment charge has fueled a boom in behind-the-meter BESSs, saving some customers millions of dollars per year. Similarly, in the U.S., third-party developers are installing behind-the-meter BESS projects to mitigate high demand charges. Typically, the developer and the customer share the savings, or execute a power purchase agreement.

Recent fires at some large BESS installations have prompted owners and operators of large BESSs, as well as regulators, to monitor these systems even more closely. For instance:

South Korea

In 2018, 23 fires in large BESSs rocked that nation's booming utility-scale BESS sector. Poor battery management, rather than manufacturing issues, was reported to be at fault.

Southwest U.S.

An April 2019 explosion in a BESS owned by Arizona Public Service injured eight firefighters. The cause is still under investigation.

Careful design, protection systems, monitoring, operation, and maintenance can promote BESS safety. Also, people are essential to keeping utility-scale BESSs safe. More education, communication, support, and guidance are needed to ensure effective collaboration among all stakeholders. Contracts and safety standards for BESSs are useful focal points for these discussions.

THE BESS BUSINESS CASE:

1. BALANCING SAFETY AND PERFORMANCE

Utility business models are evolving toward services other than generating electricity and selling kilowatt-hours to customers. "In the next 10 to 15 years, there will be less value in the generation side of the business and more money in offering flexible access to energy services," said Alistair Steele, senior consultant for DNV GL's U.K. Energy Storage Team. "The future of energy, and especially for renewables, makes investments in BESS attractive to many utilities. This technology can support grid stability within an increasingly dynamic power system."

The U.K. BESS market for grid-scale storage was kick started in 2016, with the Enhanced Frequency Response product from National Grid contracting 200 MW. Subsequent projects focused on Firm Frequency Response and the Capacity Market as the main use case. "That was reasonably lucrative at the time," said Steele, "The value of frequency response has dropped by about two thirds as more flexibility providers compete with traditional generating assets. As systems reach a high percentage of renewables, the need for fast responding assets is anticipated to increase – batteries are well placed to meet this need."

Ireland is an interesting emerging market for grid-scale BESSs. Between 2008 and 2018, installed wind capacity in Ireland tripled, to over 3,500 MW. "Network operators there are concerned about the lack of system inertia with that amount of wind," said Steele. "The variability of wind requires extremely fast frequency response. That's doable for batteries, but onerous. The big unknown is: how long will your battery last based on an unknown profile of a 15 year asset life? It's hard for investors to get comfortable with that uncertainty."

Steele noted that most U.K. grid-scale BESSs being deployed today are considering price arbitraging on day-ahead wholesale or merchant energy markets. Capacity markets had promised significant growth for U.K. BESSs, to compete against gas-fired turbines for covering loss of capacity on a system. However, recent changes in U.K. capacity market rules effectively shut out BESSs, increasing uncertainty.

Versatile energy storage technology can respond instantly, provide, frequency regulation, compensate for fluctuating renewable-energy output and microgrids. A strong business case for utility-scale BESS investments almost always requires stacking revenue and savings from multiple BESS services. However, a BESS cannot always play these roles simultaneously.

"You can't always stack revenue streams concurrently, and some streams are mutually exclusive," said Davion Hill, DNV GL's energy storage leader for the Americas. "The trend toward flexibility of use cases makes it more complex to balance safety and performance, though it can be done."

Economic performance matters, and safety and reliability impact economic performance. Installing state-of-the-art monitoring and fire protection may increase BESS costs and consume precious space. However, if a significant fire occurs, all or most of a utility's BESS investment could be erased through lost revenue, repair costs and liability settlements.

BESS fire safety typically includes monitoring and sensors, fire-suppression equipment, required setbacks, ventilation and egress requirements, and access to fire hydrants. Space limitations constrain how much capacity can be installed. This, in turn, can limit revenue or savings. Space considerations are complex for outdoor systems in close proximity to neighbors, and even more challenging for indoor systems within occupied spaces.

"There are smoke detectors and other sensors inside the battery cabinet, as well as outside," said Jason Goodhand, global business lead for energy storage at DNV GL. "However, the cells aren't the only source of fire risk. A fire could start in the cables, circuit board or other connected component. Thus, it's necessary to constantly compare sensor data to operational data."

Fire suppression for a large BESS can be tricky. Since cells are densely packed, cells that are no longer burning after a fire can remain at risk for hours after extinguishing if the electrical, thermal, and mechanical damage actors haven't been neutralized. **The gases that can be released by damaged cells, if not well ventilated, can increase the risk of explosion.** Conventional firefighting techniques must be adapted for this new and unusual situation, but the good news is that in many cases, with proper ventilation while cooling the battery cells with water, explosion hazards can be managed while slowing down cascading thermal runaway.

One of the most effective safety features of utility-scale BESSs is cascading protections: measures that prevent cascading thermal runaway (heat transfers from cell to cell).

Other safety measures include:

+ Eliminating contamination during manufacturing
+ Enhanced packaging for shipping the BESS
+ Safeguards during system integration
+ Cross-check procedures for electrical, thermal, and mechanical damage threats during commissioning, operation, and safety response

Also, software that automates BESS operation should be configured with thermal management in mind, to avoid situations that might cause heat buildup or otherwise stress the battery. This largely depends on how battery cycling is controlled and how the cooling system is designed -- a consideration that can, in turn, affect the economics of a BESS.

2. WHO'S WORKING TO IMPROVE BESS SAFETY

The first generation of utility-scale BESS deployments has provided ample information to help organizations and governments to find better ways to keep BESSs operating safely and performing well.

In North America, recent government and industry efforts include:

- NYSERDA guidebook for local governments and BES developers, March 2019.
- GRIDSTOR Coalition recommended practice for the safety, operation and performance of grid-connected energy storage systems, September 2017.
- New York City Energy Storage System Permitting and Interconnection Process Guide, April 2018.
- Energy Storage Association Corporate Responsibility Initiative, announced April 2019.
- Electricity Storage Handbook, 2013, by the U.S. Department of Energy (DOE), the Electric Power Research Institute and the National Rural Electric Cooperative Association.
- Energy Storage Safety Working Group, U.S. DOE Office of Scientific and Technical Information.
- Considerations for ESS Fire Safety, 2017, by Consolidated Edison and NYSERDA, with DNV GL.

Additionally, several organizations are working on fire codes and suppression strategies that account for the unique nature of Li-ion battery fires:

- International Fire Code, Chapter 12: Energy Systems, 2018.
- National Fire Protection Agency, Code 855, proposed 2020 standard.
- NFPA safety training for energy storage systems.
- Underwriters Laboratories 9540A, released June 2018.

Safety standards that are produced by emergency responders and product-testing organizations tend to offer conservative prescriptions. These organizations must address entire markets universally. For example, in the NFPA code, the phrase "unless testing proves otherwise" is inserted frequently to account for this.

Consequently, utilities and developers considering BESS deployments should engage with local and state governments and emergency responders during the design and engineering phase of these projects. Using best practices in mitigating cascading fires, collaborative planning may discover better safety solutions with less potential effect on BESS performance and economics.

Contracts should require that the BESS aligns fully with safety codes for all relevant authorities having jurisdiction. This can be a good opportunity to engage with local officials to get their perspective and enable them to appropriately update their emergency-response capabilities. Also, response time should be contractually guaranteed. "The owner or operator of the BESS should have a clear, realistic requirement for the contract's guaranteed response time for safety issues," Hill said. "The maintenance provider should make a firm commitment to arrive on-site within X number of hours."

Technological innovations in Li-ion battery technology may reduce fire risk without greatly sacrificing performance. One such effort is the Soteria Battery Innovation Group (BIG): a consortium of companies dedicated to eliminating self-ignition in Li-ion batteries. In the Soteria battery architecture, the drop-in separator and current collector technology helps prevent internal cell short circuits from escalating into thermal runaway. Soteria-modified battery cells have even demonstrated continued operation after a puncture. All of this is possible without fundamentally modifying the battery chemistry or its construction; the collector and separator are a drop-in solution for today's Li-ion batteries.

The Soteria consortium is building an open innovation platform around the Soteria architecture. Each member company uses its own core expertise to advance the technology.

"Think of Soteria as Android, but for Li-ion battery systems," said Brian Morin, CEO of Soteria BIG. "It's a technology platform that allows open innovation on top of the basic platform by licensing technology to battery manufacturers. It's intended to deliver safety while reducing weight and overall cost."

If the technology of larger BESSs becomes intrinsically safer, that will expand siting options that might benefit more network operators and customers. For instance, it could become easier to site a utility-scale BESS closer to key loads and customers. Safer battery technology that reduces costs and saves space also would support stronger business cases.

"When cells are safer, that reduces the sizing of external fire mitigation and suppression systems," Morin said. "For instance, a BESS might utilize fiberglass insulation, rather than bulkier and costlier ceramic fiber insulation."

As Li-ion battery technology gets safer, this will likely influence the evolution of standards and ordinances to allow more cost-effective, high-performing utility-scale BESSs. Manufacturers and utilities can engage with the bodies that set relevant standards, codes and ordinances for product safety and fire safety to ensure that everyone is working from a current, realistic understanding of BESS technology and safety.

3. SMARTER CONTRACTS FOR BETTER SYSTEM PERFORMANCE

As network operators negotiate with manufacturers and integrators to acquire their own BESSs (or to secure grid-connected BESS capacity via third parties), contracts and other written agreements increase clarity and accountability around safety and performance.

"The manufacturer's battery warranty is the first layer of protection, ensuring that a BESS will never drop below a certain capacity," Hill said. "Whether the warranty is realistic depends on how diligent the manufacturer has been about evaluating use cases."

Hill cautioned that manufacturer warranties are not always adequate to what happens in the field. "When we advise clients on BESS procurement, we look for technical gaps in the contracts. Are the batteries well suited to the use case? Was manufacturer testing appropriate? How strong is the 'back to back' chain of guarantees between parties?"

Another key agreement is the BESS' availability guarantee. Typically, this comes from the maintenance provider, which is usually the engineering, procurement and construction (EPC) company that builds and operates the project.

Clear accountability spelled out in contracts can help utilities understand who's really responsible for BESS risk. "The EPC is trying to get market share and make the sale. So they'll often guarantee capacity because they want the business," Goodhand said. "But are they fully responsible for the systems they're selling? This isn't always transparent. The contract is the tool for making those responsibilities very clear."

Whether contract terms are appropriate depends on how a BESS is likely to be used. Contracts should allow commercial flexibility and assign accountability for functions that are not part of the initial use case. For this reason, in 2018, the California Public Utilities Commission approved rules for BESSs that can provide multiple services. These rules set priorities among different types of uses, setting reliability services as the top priority.

"Know how flexible you can be without violating the warranty or contracted market obligations," Hill said. "From the owners' perspective, write things into contracts that give you flexibility in the future."

For instance, a throughput cap provision allows the BESS owner to adapt to future changes in the market. Furthermore, contracts can stipulate renewal periods or expiration dates, which can allow the owner to abandon the initial planned application and try something else, as circumstances change and opportunities arise. An extended-warranty package might be needed to cover risks associated with this flexibility.

"Before you buy, make sure you model different use cases, including blended use cases and future potential use cases if the longevity of the initial value stream is highly uncertain," Goodhand advised. "That can be an eye-opener for the possibilities and limits of a BESS. Many developers are speculating on finding value later and reconfiguring the system for a different use."

The 2018 DNV GL Battery Performance Scorecard offered these recommendations (based on independent testing) that can influence BESS contract terms and system design:

Avoid blanket assumptions.

"Batteries of similar chemistry will have varying sensitivities to degradation."

Take a holistic view.

"Consider the alignment of the battery chemistry, the battery management system, and the energy management system when evaluating battery lifetime, performance guarantees, and warranties."

Size appropriately.

"Consider the system size and power capability, compared to the expected power conditions."

What happens outside the battery matters, too.

"Consider the effects of the cooling system and the climate for the battery when considering the effects of temperature on battery lifetime, performance guarantees, and warranties."

Pre-register for the 2019 Battery Performance Scorecard, expected in October 2019.

CONCLUSION:
TIPS FOR PLANNING A SAFER, BETTER BESS

After advising many utilities, developers, lenders, ISOs, governments, and large organizations around the world on BESS deployments, DNV GL recommends these five measures to ensure project safety and success:

1. Back-calculate all tests

that the manufacturer and EPC contractor should have done. Make sure their assumptions and tests are realistic and their results are replicable.

2. Negotiate a strong performance guarantee,

as well as a sufficiently flexible warranty and/or throughput cap.

3. Model the effects of changes to the BESS use case.

Understand potential effects to safety, performance and contracts when changes or additions to the initial use case are made after deployment.

4. Education and engagement.

Communicate early, clearly and often with stakeholders about the planned uses, benefits and risks of planned BESS deployments. Be prepared to educate stakeholders, and listen carefully to their questions and concerns.

5. Work with an owner's engineer/technical advisor,

from earliest project planning, including for contract negotiation. Reputable, independent experts often make the most effective advocates for the interests of BESS buyers – from RFP and contracting through commissioning and beyond.

Investing in all these elements yields a BESS that is more likely to be a wiser, safer and more lucrative investment. It also means that major investments in utility-scale BESSs are less likely to be suddenly lost to fires or other catastrophic damage.

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