




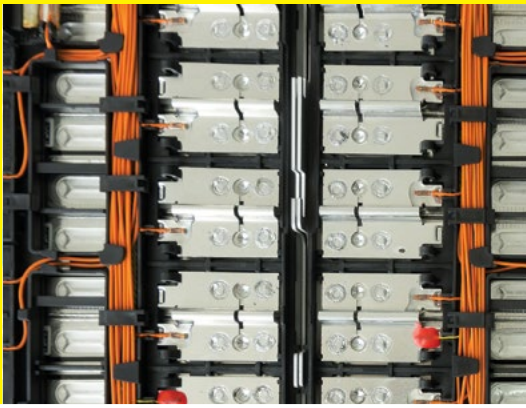

2025 White Paper

Community-Based Siting and Permitting for Grid-Scale Lithium Ion Battery Storage

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EXECUTIVE SUMMARY

Deployment of grid-scale battery energy storage facilities is accelerating rapidly. Challenges to siting and permitting are emerging due to a combination of factors, some applicable to all large energy projects and others specifically associated with lithium ion battery technology. This white paper reviews key developments in the siting and permitting of battery storage facilities and addresses environmental, health, and safety issues, along with jurisdictional questions and community benefit considerations.

Early grid-scale battery storage facilities generally drew limited scrutiny from permitting authorities and the public due to their novelty—both in terms of technology and land use—and relatively small size, as well as the lack of specific regulations and requirements. The battery technology itself was treated as a ***black box***, labeled on indicative site plans but not characterized in detail. A 2019 battery failure incident triggered an industry-wide transition to ***open book*** treatment of fire safety considerations. Since then, continually enhanced codes and standards have raised the bar for technologies deployed in grid-scale applications and imposed myriad building, design, and hazard mitigation requirements to support information exchange among developers, host communities, and jurisdictional authorities. Present best practices feature ***direct engagement*** among developers and fire safety officials. Expansive dialogues about technology specifications, safety issues, training needs, emergency response plans, and related issues are complemented by commitments to design and construct grid-scale facilities to at minimum meet the most recent versions of codes and standards, even if that is beyond applicable requirements in specific locations.

Until recently, the patchwork of local land use and zoning and state-level siting and permitting and the proactive approaches taken by responsible developers—bolstered by codes, standards, and best practices—seemed adequate for ensuring widespread storage adoption. The rising tide of community-based opposition, which is often driven by fire safety concerns and aggravated by misinformation, and the massive scale of deployment, as implied by clean energy and emission reduction targets, highlight the inherent tension between local control and higher-level governmental mandates. Grid-scale battery storage facilities are experiencing longer development time lines—doubling in some instances—and higher siting and permitting costs, along with high rates of project cancellation.

This white paper concludes with reviews of experiences in the renewable energy sector, environmental health and safety considerations and community benefits associated with grid-scale storage, and the potential for the energy-related services delivered by storage batteries to be leveraged for de-conflicting siting and permitting and building public acceptance. The ***social license*** approach—drawing on outreach and engagement methods developed for enabling adoption of new and emerging technologies facing acceptance challenges—is recommended for supporting the siting and permitting of future grid-scale battery storage facilities. Possible next steps for EPRI research also are identified.

OVERVIEW

Grid-scale battery energy storage system (BESS) technology can help meet growing needs for clean, affordable, and reliable electricity while providing economic, environmental, and equity benefits in host communities and regions. Across the global spectrum of applications, this technology can help deliver the power quality, security, and resilience needed in the industrialized world, as well as improve living conditions and address historical inequities in developing and underdeveloped regions. In addition, BESS technology is recognized in academia, government, and industry as a key solution for helping power grids incorporate the high levels of variable solar and wind generation required to achieve renewable energy, decarbonization, and climate goals over both the near and long terms.

Dramatic cost reductions and growing market opportunities are driving rapid increases in the deployment and development of grid-scale lithium ion storage facilities. Cumulative US BESS capacity surpassed 1 gigawatt (GW) in 2020, 10 GW in 2023, and 20 GW by mid 2024. Interconnection queues feature hundreds of gigawatts of both standalone BESS facilities and storage + renewables plants, and cumulative US capacity is projected to exceed 70 GW by 2027. (Colthorpe, 2023; Gorman *et al.,* 2023; Wood Mackenzie Power & Renewables and American Clean Power Association, 2024; US Energy Information Administration, 2024) Terawatt-scale deployment is anticipated globally around 2030. (International Energy Agency, 2023)

The expansion in operational and announced BESS projects is fueled by rising demand for storage capacity, attributable largely to the increasingly attractive economics of renewable generation across the past decade and by the market opportunities—bolstered by new incentives—created by the need to accommodate and balance renewables and build resilience within and across grid control areas. As operational and proposed BESS facilities proliferate in the US and other countries, challenges to siting and permitting are emerging due to a combination of factors, some generic and others unique to lithium ion battery storage.

Large energy infrastructure projects generally face multi-agency and multi-level reviews—and the potential for community-based opposition—leading to increased development timelines, costs, and risks. (Hanley, 2023) BESS-specific siting and permitting issues revolve around the novelty of lithium ion battery technology and its environmental, health, and safety (EH&S) attributes. Of particular concern are the misinterpretation of news reports regarding fire safety, the lack of authoritative information and context regarding perceived versus actual risks, and the broad availability of inaccurate and misleading information about observed failure events at utility-scale facilities.

Lithium ion battery products of all kinds and sizes can pose fire safety concerns based on the ignitability of electrolyte materials, but risks vary based on design, size, application, and other factors. Like today's electric vehicles (EV), BESS facilities are based on large-format lithium ion battery cells built up into bigger and more powerful modules. Grid-scale technologies are productized as integrated, often containerized systems that can be deployed as individual units or in larger arrays. The cells, modules, and integrated systems used in today's grid storage applications are required to meet stringent and comprehensive fire safety and protection standards and codes, driven by the flammable nature of the materials they contain and by the lessons learned from previous failures. (EPRI, 2023a)

The global number of observed safety incidents for grid-scale storage plants averaged about 12 annually from 2018-23, when cumulative worldwide deployment increased by about 50-fold as shown in **Figure 1**. (EPRI, 2024a, 2024b) By contrast, more than 500 battery fires occurred in micro-mobility devices—such as electric scooters and bicycles—

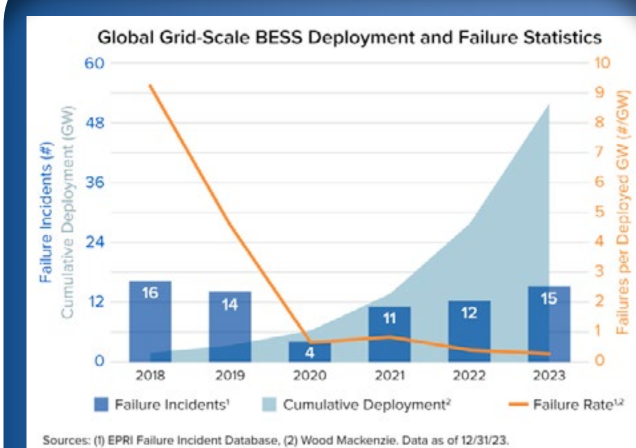

Figure 1. *The rate of observed BESS failure incidents has declined as deployment has grown.*

during the first half of 2023 alone. (EPRI, 2023b) Industry experience shows that existing requirements and best practices in the areas of product design and manufacturing and in the development, engineering, procurement, construction, commissioning, and operations and maintenance (O&M) of utility-scale BESS facilities can prevent rare events from harming people or the environment.

Based on its cost-performance attributes, grid-scale lithium ion battery storage is positioned to achieve its potential in meeting clean energy, outage prevention, equity, and other goals, but favorable characteristics and an excellent safety record are not sufficient to ensure deployment at the scale needed. This white paper reviews key developments in the siting and permitting of BESS facilities and focuses on community-based considerations with the objective of helping electricity providers, project developers, government agencies, jurisdictional authorities, the public, and other stakeholders engage, communicate, and collaborate to overcome deployment barriers. It is based on interviews with project developers and permitting consultants and reviews of publicly available information resources, including permitting dockets and submissions reported on in prior work. (EPRI, 2021a, 2022a)

EVOLVING EXPERIENCE

Throughout this ongoing, relatively early stage of BESS deployment, proposed projects often represent the first time a community is introduced to grid-scale lithium ion battery technology. Upon learning of a proposed BESS facility, landowners, officials, neighbors, and other stakeholders commonly ask questions such as the following: What is battery storage? Why here? How are my needs being met? What are the real EH&S risks?

Utility-scale BESS facilities can supply energy, control, and other grid support services to maintain power quality and reliability, reduce outage frequency, integrate renewable resources, and meet additional needs on an instantaneous, hourly, or daily basis. Facilities generally are sited near substations to reduce capital costs and transmission losses and often are deployed in combination with solar or wind generation to provide balancing and increase the time value of renewable energy. Financial viability depends on grid conditions and related policies and markets and is usually enhanced if multiple value streams are available for BESS owner and operators. (EPRI, 2023c, 2022b)

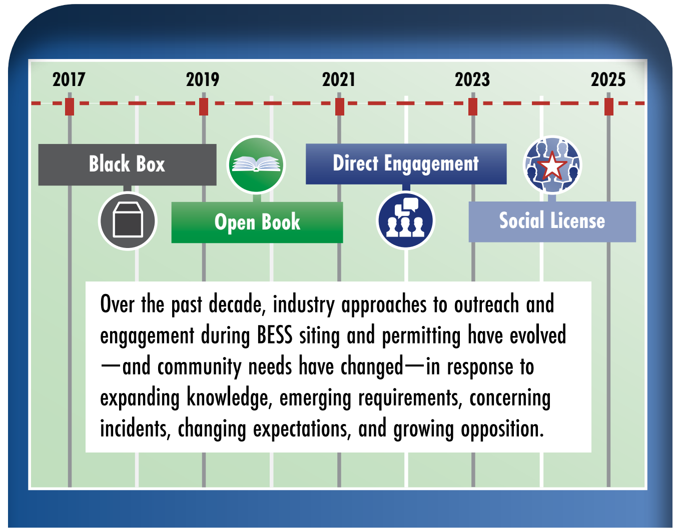

Figure 2. *BESS facility developers have adjusted outreach and engagement practices to meet current needs.*

Comparing and contrasting grid-scale facilities to familiar, widely used consumer products that rely on rechargeable lithium ion batteries for power—such as cell phones and laptops—can provide a starting point in building familiarity with BESS technology. Bringing officials, residents, and stakeholder groups further up the learning curve on EH&S considerations and the potential for localized benefits is an essential component to successful BESS siting and permitting, but recent experience indicates that deeper engagement is necessary.

Figure 2 illustrates how BESS siting and permitting have evolved over time. Prior to 2019, grid-scale facilities generally drew limited scrutiny due to novelty—both in terms of technology and land use—and relatively small size, as well as the lack of specific building regulations and requirements. Additionally, a number of early deployments involved emergency grid reinforcement projects and inside-the-fence sites, either at existing utility substations or at operational solar power plants that had been approved in years prior.

In 2016-2017, for example, several grid-scale storage facilities in California progressed from initial site visit through permitting, project approval, and construction to commissioned installation within 6 months. (Pyper, 2017) At one such site, local officials initially assumed that the BESS plant—proposed as a pre-engineered building on a concrete pad—would be akin to a self-storage facility but used for warehousing large numbers of batteries prior to retail sale. Field inspections conducted prior to BESS operation focused on compliance with electrical and building codes and requirements for outdoor lighting, parking, and the like. Cabinets containing battery modules were not even opened.

Reviews of US permitting dockets and documents indicate that BESS facility developers and authorities having jurisdiction (AHJ) commonly treated the battery technology itself as a ***black box***, labeled on indicative site plans but not characterized at any level of detail. Project narratives and other submittals often lacked basic information such as cell chemistry, battery manufacturer, and system integrator and did not acknowledge that lithium ion modules must be transported, handled, and managed as hazardous materials. Proposed mitigation measures emphasized community concerns common to all large land use development projects, such as traffic and other construction impacts, operational noise, and aesthetics. Needs for special care in the areas of fire protection, explosion prevention, public safety, and emergency planning and response were not discussed in a number of instances. (EPRI, 2021a, 2022a)

According to one developer, multidisciplinary emphasis on preventing cell-level failures from creating fire safety hazards at BESS facilities could have begun earlier but "the grid storage industry did not know what it did not know." Additionally, many AHJs did not afford these facilities the same level of scrutiny applied to other forms of energy infrastructure presenting known hazards, such as fuel stations, pipelines, and storage tanks and fossil power plants. In fact, research to understand thermal runaway in lithium ion batteries and develop mitigation measures began in the 1990s—initially in response to high-profile events involving consumer electronics and eventually encompassing failures of large-format EV and BESS technologies. (DNV GL, 2020)

Codes and standards for stationary storage applications began emerging more than a decade ago, as follows:

- In 2013, Underwriter's Laboratory (UL) released the first edition of *UL 1973: Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications* specifying design, construction, testing, and other requirements for dozens of parameters that must be met at the cell and then the battery level. (UL, 2013)
- The first editions of UL standards specific to stationary storage products and thermal runaway fire propagation were released in 2016-17 as *UL 9540: Standard for Safety of Energy Storage Systems and Equipment* and *UL 9540a: Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*. (UL, 2016, 2017)
- Analogous requirements under the International Electrical Code (IEC) were first released in 2014 as *IEC 62620: International Standard, Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Secondary Lithium Cells and Batteries for Use in Industrial Applications* and in 2017 as *IEC 62619: International Standard, Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Secondary Lithium Cells and Batteries for Use in Industrial Applications.* (IEC, 2014, 2017)

Some battery storage developers and AHJs were attentive to these standards and to fire safety concerns from the very beginning. A significant incident in Arizona triggered an industry-wide transition from ***black box*** to ***open book*** treatment of grid-scale lithium ion battery technology as shown in Figure 2. On April 19, 2019, an individual cell failure in a containerized unit at a BESS plant commissioned in 2017 propagated a larger thermal runaway event, leading to an accumulation of flammable gas and eventually an explosion that injured several firefighters. (DNV, 2020; UL Firefighter Safety Research Institute, 2020)

Since then, safety considerations have attracted far greater levels of attention from manufacturers, developers, first responders, AHJs, and the research community, and relevant standards have been continuously updated. Notably, National Fire Protection Association (NFPA) released *NFPA 855*, *Standard for the Installation of Energy Storage Systems* in 2020, addressing fire safety and emergency planning and response across the areas of BESS design, construction, commissioning, O&M, incident response, and decommissioning. (NFPA, 2020) These comprehensive requirements were included in the *2021 International Fire Code®* (IFC), and an updated version of NFPA 855 was released in 2023. (International Code Council, 2021; NFPA, 2023)

The codes and standards discussed above represent a fraction of the requirements facing technology developers, BESS facility developers, and owners and operators. (EPRI, 2023a) Continued enhancements raise the bar for technologies deployed in grid storage applications and

BOX 1—FINDING THE RIGHT SITE IN THE YUKON, WITH COMMUNITY INPUT

In 2020, Yukon Energy Corp. (YEC) identified three candidate sites for a grid-scale battery on First Nations settlement land in Whitehorse, the territorial capital of the Yukon in northwestern Canada. The originally preferred location abutted YEC's Takhini substation, a highway, and a residential property and was located within 300 m of 12 additional residential properties. (Tobin, 2020a)

The Kwanlin Dün First Nation and Ta'an Kwäch'än Council were invited to serve on a steering committee with YEC to discuss siting options and opportunities for maximizing benefits for indigenous peoples. Broader community outreach included notifications and door-knock visits to residents and businesses within 800 m of all three potential sites, plus public and stakeholder meetings. Written and verbal comments were analyzed by source and for content. (Stantec, 2020)

Commenters were almost universally supportive of YEC's plan to deploy BESS to improve the reliability of its isolated grid, reduce outage impacts, and increase reliance on renewables for meeting winter peak demand while decreasing use of diesel generators. However, the preferred site was strongly opposed by neighbors and other commenters based on its proximity to residential properties, with other candidate sites offering the key advantage of being closer to non-volunteer fire departments but not as close to residential areas. (Stantec, 2020)

In late 2020, YEC decided to abandon the Takhini substation site due to community opposition. (Tobin, 2020b) Public input was applied to inform selection of an alternate BESS location—near other industrial uses and on First Nations land identified for development, but requiring a new 1.7-km transmission line to interconnect with the Whitehorse Rapids substation. (Yukon Utilities Board, 2021)

In addition to hosting the BESS, First Nations enterprises have been involved in site preparation and construction activities under community benefit agreements. Scheduled to enter service in 2025, the 20 MW/40 MWh storage battery will be the first of its kind in the Yukon. (YEC, 2024)

impose hazard mitigation requirements addressing factors such as clearance and separation distances and fire suppression, ventilation, and explosion control measures. They also provide a clear framework for communications among developers, host communities, and AHJs and for BESS-specific regulation. However, the latest NFPA, IFC, and other requirements are not universally applicable because states and other authorities generally implement updates on independent schedules, and local AHJs may not be allowed to exceed state standards. (EPRI, 2023a; Twitchell, 2022)

Per Figure 2, current best practices in siting and permitting feature ***direct engagement*** with local fire departments and public safety officials complemented by commitments for design and construction of BESS facilities to at minimum meet the most recent versions of codes and standards—particularly for NFPA 855—even if that is beyond applicable requirements in specific locations. (EPRI, 2021b) Increasingly, developers, local officials, and AHJs are participating in expansive dialogue about battery technology specifications, safety requirements, plans and precautions, and other issues that must be addressed to the satisfaction of fire departments charged with ensuring public welfare. Collaborative development of community-based emergency preparedness and response plans is common—and increasingly required. In some cases, technology selection is occurring and detailed engineering is beginning earlier in the project development process in order to provide the requested and required information. This can involve additional early investment and can create procurement risks but offers the benefit of collaboration toward shared goals.

According to experience to date, increased coordination and communication with local officials and communities around a preferred site is more likely to lead to minor project modifications than major changes in battery or fire mitigation technologies. Sample modifications include adjustment of access road configurations to provide adequate turnarounds for emergency vehicles, of facility designs to increase separation distances between containers and from nearby receptors, and of security, lighting, and landscaping plans to address concerns over noise and visual impacts. Such measures can result in reduced capacity or higher costs but also increased certainty. In some cases, choosing an alternate site can represent the best path forward as exemplified in **Box 1**.

JURISDICTIONAL CONSIDERATIONS

Across much of the US, BESS facility siting is subject to municipal zoning and land use regulations and ordinances, including codes and standards adopted by reference or at the state level. Typically, cities and towns serve as AHJs in determining acceptable uses within the borders, and counties have authority in unincorporated areas. The number of US municipalities with zoning ordinances that specifically reference BESS remains small but is growing**.** (Twitchell *et al*., 2023) Early adoption of local zoning provisions has sometimes been intended to establish grid-scale storage as an allowable use but increasingly is aimed at ensuring safety or restricting BESS deployment.

In the usual case where grid-scale BESS is not specifically authorized, AHJs—from individual officials to boards to agencies—can have significant discretion, with requirements varying significantly. The discretion lies with property owners in unincorporated areas of Alabama, Oklahoma, and Texas where land use regulation is precluded by state law. (Lo, 2019) Broadly, construction-related and EH&S permits are awarded—and building, electrical, fire, and other final inspections are conducted—by municipal officials. The involvement of local interests in BESS siting and permitting results in significant variation in expectations, processes, and requirements. It also creates opportunity for community benefit and potential for difficulties, delays, and successful opposition.

State-level facility siting boards and public service commissions—often created decades ago to facilitate the permitting of utility-scale electricity "generation" and "transmission" infrastructure—can have superseding authority over local and regional zoning of grid-scale storage, depending on project size and other factors. These entities can offer the benefit of established processes and requirements, consolidated permitting, and zoning relief but have traditional limitations in terms of extended review timelines and recently acknowledged constraints in terms of public engagement and broad community involvement. Statutory definitions are key in determining jurisdictional authority, in that BESS facilities do not "generate" or "transmit" electric energy, instead acting like a consumer when being charged and then supplying previously generated energy during discharge. This lack of alignment can create challenges.

For example, in the absence of guidance under the UK's 1989 Electricity Act, the Office of Gas and Electricity Markets (Ofgem) decided in 2020 to regulate electricity storage as a subset of generation. This created a requirement for storage providers to become licensed generators and an administrative barrier precluding fuel suppliers and network providers from operating BESS facilities. The UK's 2022-23 Energy Bill addressed these limitations by amending the 1989 act to classify electricity storage as a distinct subset of electricity generation, with the energy being stored for the purpose of being converted back into electricity. (Murray, 2022a; Mawhood, 2023) Similarly, Germany's Bundestag, the federal parliament, amended existing laws in 2022 to define energy storage as an asset where "the final use of electrical energy is postponed to a later point in time than when it was generated." (Murray, 2022b) Such clarifications can be foundational steps toward the development of storage-specific regulatory frameworks.

Grid-scale "energy storage" facilities are explicitly under state-level purview in some cases, including in Connecticut and in Vermont as of 2019. (Connecticut General Statutes, 2023; Vermont General Assembly, 2019) In 2014, New York's state-level siting authority applied a definitional basis in declining to assert jurisdiction over a first-of-a-kind standalone BESS facility proposed in a partial repowering of the Ravenswood Generating Plant in Queens. (New York State Board on Electric Generation Siting and the Environment, 2014) In May 2023, the Massachusetts Energy Facilities Siting Board (EFSB) made a similar decision in its initial deliberation on BESS siting, addressing the proposed Cranberry Point Energy Storage facility in the town of Carver. (MA EFSB, 2023) Just a couple months later, the Massachusetts Department of Public Utilities (DPU) determined that the same facility—on the lengthy and complex approval pathway illustrated in **Figure 3**—was exempt from Carver's evolving land use and zoning requirements, concluding that non-utility BESS developers meet the statutory definition of a "public service corporation" in the state's restructured electricity marketplace and under its clean energy and net-zero targets. (MA DPU, 2023)

Even where not covered by definition, BESS siting and permitting can be subject to state authority if considered "ancillary" to jurisdictional facilities—for example, solar farms, wind projects, or even transmission infrastructure. (Flavin,

PERMITTING EXPERIENCE: UNCERTAIN PATHWAY & LOCAL OPPOSITION

*The extended and circuitous permitting process for the **Cranberry Point Energy Storage Facility** in Carver, Massachusetts—the state's first utility-scale BESS—illustrates key challenges associated with deploying new technology in a dynamic environment. The site for the 150 MW/300 MWh facility was selected in 2017 based on state goals, access to forward capacity and clean peak markets, and the neighboring substation. The nearest residence is about 125 m away, and hundreds of homes are within about 250 m. Due to regulatory uncertainty and then vocal opposition, the development timeline doubled, at significant cost. As illustrated, two different approval pathways were pursued:*

1. *Initially, the developer worked with town officials to amend zoning bylaws, address fire safety and abutter concerns, and secure local approvals while arguing that BESS facilities are not under state jurisdiction by definition. The state's jurisdictional determination process required no community involvement—but also lacked a timeline for completion.*
2. *After an ownership change and 2 years of deliberation, the new developer initiated community outreach and petitioned for EFSB jurisdiction. This alternative pathway required direct notification, catalyzing local opposition and 2 additional years of state review. Citizen-driven zoning amendments were enacted to stop the project but rejected by the AGO. EFSB declined to assert jurisdiction. DPU finally granted a comprehensive zoning exemption.*

KEY Developer | Local | State

EFSB = *Energy Facilities Siting Board* **AGO** = *Attorney General's Office*
DPU = *Department of Public Utilities*

2 LOCAL OPPOSITION + REQUESTS FOR STATE JURISDICTION & COMPREHENSIVE ZONING EXEMPTION

2021

6-7/2021: New developer announces project, with planned 2023 construction and 2024 startup, and hosts an open house attended by two residents/property owners

8/2021 - 5/2023: Developer petitions EFSB for consolidated permitting, stipulating that proposed BESS is a "generating facility" and is thus jurisdictional by definition (EFSB)

2022

COMMUNITY ENGAGEMENT — YES ☑ NO ☐ — CITIZENS GUIDE TOWN OFFICIALS

1-4/2022: Citizens develop and voters approve zoning amendment imposing 11.5-month moratorium on BESS and directing officials to develop BESS-specific bylaw (AGO disapproves as unlawful due to prohibition of solar-related land use) (VOTE)

5/2022 - 6/2023: Developer petitions DPU for comprehensive zoning exemption because proposed BESS qualifies as a "public service corporation" and due to "politicization of storage" (DPU)

COMMUNITY ENGAGEMENT — YES ☑ NO ☐ — HUNDREDS OF LOCAL COMMENTS; OPPONENTS INTERVENE

11/2021 - 4/2023: Processes involve published notice, abutter and neighbor notification, public hearing, agency and intervenor discovery, and evidentiary hearing. Developer responds to more than 300 questions and information requests from state agencies, opposition group, and other intervenors.

7/2022: Town officials unanimously oppose developer's request for comprehensive zoning exemption

2023

1-4/2023: Officials develop and voters approve zoning amendment increasing setback requirements plus new BESS-specific bylaw, both essentially precluding proposed site (AGO warns that preventing or unreasonably restricting BESS would likely be unlawful) (VOTE)

5/2023: Developer appeals to state agencies indicating that protracted review process threatens viability of this and other BESS projects

5/2023: EFSB determines BESS is not a "generating facility" and thus not subject to jurisdictional authority

6/2023: DPU determines BESS facility is a "public service corporation," approves zoning exemption, requires mitigation of environmental and community impacts, and recommends compliance with local permit conditions

8 & 12/2023: Developer secures deferral of capacity obligation to 2025, then commences construction with planned 2025 startup

1 LOCAL APPROVAL + REQUEST TO STATE FOR NON-JURISDICTIONAL DETERMINATION

2017

1-10/2017: Original developer completes screening process and selects preferred site adjacent to utility substation, other infrastructure, and cranberry bogs

COMMUNITY ENGAGEMENT — YES ☐ NO ☑ — TOWN OFFICIALS GUIDE CITIZENS

LATE 2017: Developer reaches out to town administrator/planner on selected BESS site, need for zoning accommodation, and opportunity for tax revenue

2018

1-4/2018: Officials develop and voters approve zoning bylaw amendment establishing BESS as an allowable land use (VOTE)

LATE 2018: Developer reaches out to fire safety/other officials, leading to minor design modifications and commitment to support emergency response planning after BESS technology selection

2019

2/2019 & 2/2020: Aiming for 2020 construction and 2021 startup, developer participates in forward capacity auctions but is not awarded a contract to deliver capacity starting in 2022 or 2023

2-3/2019: Conservation Commission and Planning Board award conditional approval and site plan review/special permit

1/2019 - 7/2021: Developer petitions EFSB for determination that BESS is not jurisdictional by definition, local zoning and permitting afford protections, and EFSB review will delay progress toward state goals (EFSB)

COMMUNITY ENGAGEMENT — YES ☐ NO ☑ — NO PUBLIC HEARING, NO INTERVENORS, AND NO LOCAL COMMENTS

3-5/2019: Process involves published notice and agency discovery. Developer responds to 86 questions and information requests from state agencies.

2020

6/2020: NEW DEVELOPER purchases interest in BESS facility

2021

2/2021: Developer is awarded 7-year capacity contract starting in 2024

3/2021: Developer requests, and Planning Board approves, extension of construction start deadline

6-7/2021: Developer withdraws request for non-jurisdictional determination after protracted agency deliberation

Figure 3*. Lack of clear approval pathways and local opposition can result in extended and costly siting and permitting delays. (MA AGO, 2022, 2023; MA DPU, 2023; MA EFSB, 2023; Carver Concerned Citizens, 2023; Cranberry Point Energy Storage, 2023)*

***Figure 4**. Current BESS facility designs typically include minimum separation distances between containers for batteries and ancillary equipment, as well as myriad other safety features.*

2020) In 2022, California joined Washington and other states by enacting Assembly Bill (AB) 205 to allow developers of grid-scale storage projects to choose state-level siting review, and New York is considering a similar approach. (Biss, 2024; Washington State Legislature, 2024)

Siting of grid-scale BESS on US federal property identified as suitable for the development of renewable energy and related facilities is subject to review by the US Bureau of Land Management (BLM) under provisions of the National Environmental Policy Act, but these well-established standards do not address BESS-specific issues. As is generally the case with state-level jurisdictional authorities, BLM's approval is conditioned on compliance with other applicable regulations, codes, and standards. For example, BLM recently approved a 150 MW/1200MWh storage facility located within the right-of-way issued for the first phase of the Alta Wind Energy Center in California. The Kern County Fire Department (KCFD) remains responsible for permitting and enforcement under the *California Fire Code* and NPFA 855. (BLM, 2024; Panorama Environmental, 2023; KCFD, 2022, 2023)

RISING CONCERNS

BESS development activity is rapidly increasing in established markets, additional markets are opening up, and experienced developers and new entrants are competing both for sites and spots in interconnection queues. In parallel, media reports of battery fires and failure incidents involving micro-mobility devices as well as EV and grid storage applications are proliferating, and these reports often lack proper context. (EPRI, 2023b, 2024b) This can give pause to neighbors of existing BESS facilities and to citizens, stakeholders, and decision-makers in communities and regions where grid-scale projects are under consideration or in permitting—or might someday be proposed.

Internet searches on "lithium ion battery fires" and "battery safety" provide immediate access to videos and images of flames and explosions plus millions of other resources, covering the gamut from fact-based and even-handed to incomplete, inaccurate, and misleading. Intentional and methodical community outreach aimed at addressing legitimate but manageable BESS safety issues can be undermined by misinformation or disinformation found online,

BOX 2—(MIS)LEADING SAFETY SOURCE

In 2021, credentialed UK scientists from respected institutions prepared a technical paper, "Safety of Grid Scale Lithium-ion Battery Energy Storage Systems," for submission to the UK Parliament advocating for the UK Health and Safety Executive (HSE) to manage grid-scale BESS facilities under the "Control of Major Accident Hazards Regulations 2015 (COMAH)." (Fordham *et al*., 2021) The paper was not peer-reviewed nor accepted by an academic journal but was uploaded to the academic social networking site *ResearchGate*. In addition to including photos of battery fires and links to videos, the paper used a provocative method to characterize safety risks for a sample project, the Sunnica Energy Farm solar + storage facility proposed in a rural area east of Cambridge.

Based on BESS capacity of 1.5 to 3 GWh across hundreds of containers, the paper estimated the facility's overall explosion potential to be "2.7 to 5.5 Beiruts"—with 1 Beruit equivalent to the force of the 2020 blast that created a crater 140 m wide in the capital city of Lebanon, killed 218 people and injured 7000, left about 300,000 people homeless, damaged buildings up to 10 km away, and registered 3.3 on the Richter scale. (Fordham *et al*., 2021; *Al Jazeerah*, 2022) The attention given this estimate rests on the authors' assumption that the entire BESS would explode —an ***extremely unlikely outcome*** given that facilities are comprised of multiple modular units that incorporate active and passive safety features designed to prevent failures and explosions and also are spaced far enough apart to prevent propagation if an event does occur.

Despite not being published, the 2021 paper is a prominent technical reference in search engine output and has been quoted in UK media reports (e.g., Bradshaw, 2022). In the US, the paper is commonly cited in public testimony, submitted to AHJs, and made available on the websites of groups opposing proposed BESS installations. (e.g., Carver Concerned Citizens, 2023; Citizens for Estero Bay Preservation, 2024) To counter misleading information, EPRI recommends that BESS developers and owner/operators complete hazard mitigation analysis (HMA), failure modes and effects analysis (FMEA), and air plume dispersion modeling studies and take proactive measures to make findings and recommendations available to AHJs, fire safety officials, and the public. (EPRI, 2021b, 2022c, 2024c)

quickly disseminated, and broadly shared, as described in **Box 2.** Questions and concerns raised by individuals and groups—exacerbated in some cases by political polarization—can be sensationalized and can escalate into active and organized opposition.

This can lead to permitting delays, denials, and withdrawals or cancellations as well as the development of restrictive requirements, temporary moratoriums, and even outright bans on BESS installations. (e.g., Baker, 2021; Town of Wendell, 2022; Jones-Gorman, 2023; Twitchell *et al*., 2023; Covington City Council, 2023; Cranberry Point Energy Storage, 2023; McConnell, 2024; Orozco, 2024) Figure 3 illustrates how jurisdictional issues, exacerbated by growing public awareness and opposition, doubled the development time line for the first standalone BESS in Massachusetts. Notable responses to specific failure events have been observed in California and New York.

In California, three failure incidents occurring at standalone BESS facilities sited adjacent to the substation at Moss Landing Power Plant in Monterey County have had broad implications, even though safety systems functioned properly and no injuries, adverse health effects, or environmental impacts were experienced. The most highly publicized event occurred in September 2022 and resulted in a shelter-in-place advisory to nearby neighborhoods and the closure of an adjacent segment of Route 1, California's coastal highway. (Monterey County, 2022; Vistra, 2022a; Pacific Gas & Electric, 2022) As detailed in **Boxes 3 and 4**, these community-based emergency management responses attracted nationwide notoriety, led to legislative action, and impacted public acceptance of a BESS facility proposed at the site of the former Morro Bay Power Plant a couple hours south on Route 1.

New state legislation, drafted with input from Monterey County officials and enacted as Senate Bill (SB) 38 in 2023, amended the *California Public Utilities Code* based on lessons learned during the Moss Landing incidents and elsewhere. BESS developers and owner/operators across the state are now required to provide host communities with emergency response and emergency action plans created in coordination with local agencies and first responders. Emergency plans compliant with SB38—implemented during a November 2025 failure incident in Escondido as

BOX 3—A TALE OF TWO COASTAL COMMUNITIES: MOSS LANDING

At Moss Landing in Monterey County, 932.5 MW/3730 MWh of BESS capacity is deployed. Vistra's multi-phase Moss Landing Energy Storage Facility and the Pacific Gas & Electric (PG&E) Elkhorn BESS were approved by Monterey County Planning Commission in 2020. Owner-operators collaborated with county agencies and fire safety officials in developing emergency preparedness and response plans and conducting training, and AHJs completed fire code and other inspections prior to commercial operation. (Vistra, 2022a; PG&E, 2022; Monterey County, 2022)

Vistra's initial 300 MW BESS began operation in late 2020, and another 100 MW entered service in 2021. Both units are enclosed within retired power plant structures. Failure incidents occurred at Phase 1 in September 2021 and Phase 2 in February 2022 when water leaks from improperly installed heat suppression systems caused electrical shorts in battery racks that had been operating normally, activating alarms and hazard mitigation measures. Other safety systems functioned properly, local responders mobilized, and the incidents were managed without outside assistance or off-site impacts. (Vistra, 2022a, 2022b, 2022c; Monterey County, 2022)

In September 2022, a single container at the 182.5 MW Elkhorn BESS experienced a fire due to water ingress from an improperly installed vent shield causing shorting, overheating, and runaway. Alarms and safety systems functioned properly, and on-site personnel coordinated with responders in allowing the failed unit to burn out over several hours while preventing spread to nearby containers. Community officials closed the adjacent highway and recommended windows be closed and ventilation systems turned off in nearby neighborhoods subject to a shelter-in-place advisory. Air quality tests demonstrated that airborne emissions posed no threat to human health or the surrounding environment. Water applied for propagation prevention and soil contaminated by fire debris were collected for proper disposal with oversight from hazardous materials response officials. Subsequent testing of air and water samples showed minimal environmental impacts. (PG&E, 2022, 2023; Monterey County, 2022; Spector, 2022)

In response to these incidents, owner-operators collaborated with manufacturers, system integrators, independent experts, and local, county, and state officials to identify root causes, implement corrective measures, and update fire safety and emergency response plans. Plume modeling was conducted to quantify the impacts of failure scenarios, wind conditions, and other factors on off-site hazards and inform future decisions around possible shelter-in-place orders or road closures. All three BESS systems were returned to service by the end of 2022, Vistra's 350 MW Phase 3 BESS began commercial operation, and county officials acknowledged both the societal importance of battery storage and the continuing need to work with owner-operators and other stakeholders in addressing safety concerns. (Monterey County, 2022; Vistra, 2022a; PG&E, 2022)

In 2023, county and state officials collaborated to develop legislation amending the *California Public Utilities Code*. Under SB38, BESS developers and owner-operators must prepare emergency response and community action plans to ensure that notification procedures and other protective measures are ready for implementation in the event an incident occurs. (LegiScan, 2023)

Note: This white paper does not address the January 2025 incident at Vistra's Phase 1 unit, which remains under investigation as of the date of publication.

described in **Box 5**—must specify procedures for notifying and communicating with local emergency management agencies during a BESS incident and for ensuring the safety of the public, neighboring properties, responders, and the environment. (LegiScan, 2023; Herrera, 2023) Meanwhile, in Morro Bay, community concern crystallized into opposition, leading to a November 2024 ballot measure giving voters the ability to prevent local officials from approving BESS development at the former power plant site. (Rode, 2024)

In 2023, communities in New York began enacting temporary local moratoriums on grid-scale BESS after failure incidents in East Hampton, Chaumont, and Warwick occurred during the same period in which numerous battery fires involving micro-mobility devices stored inside buildings in New York City resulted in dozens of injuries. (EPRI, 2023b) Recognizing the critical importance of BESS technology for improving reliability and resilience and meeting energy and climate targets, New York Gov. Kathy Hochul convened an

BOX 4—A TALE OF TWO COASTAL COMMUNITIES: MORRO BAY

A couple hours south of Moss Landing on Route 1, Vistra proposed a 600 MW BESS facility at the former Morro Bay Power Plant in late 2020, shortly before the Morro Bay City Council approved a new general plan designating a portion of the partially decommissioned site for “Visitor Serving Commercial” use and requiring a new master plan prior to site redevelopment. (City of Morro Bay, 2021a) Subsequently, after negotiations with city officials, Vistra agreed (1) to demolish and remove the plant’s 9-story-tall generating building and three 137-m-high stacks by 2028 or pay the city $3 million; (2) to fund the creation of a Phase 1 master plan designating the footprint of the proposed BESS facility for “General (Light) Industrial” use and presenting conceptual visions of future uses for the remainder of the site and surrounding areas; and (3) to pursue BESS permitting and approval on a separate but parallel track. (City of Morro Bay, 2021b)

From mid 2022 through early 2023, the city conducted a visioning workshop, an online survey, and stakeholder interviews to guide master planning, as well as community scoping sessions to inform the required environmental impact assessment. Residents cited the BESS failure incidents at Moss Landing as a critical concern during the workshop, a dedicated opposition group formed soon after, and the most common sentiment across more than 600 survey respondents was strong disapproval of using the site for grid-scale storage. (City of Morro Bay, 2024a; Citizens for Estero Bay Preservation, 2024; Vistra, 2024; Rincon Consultants, 2023) As officials moved forward with master planning, opponents collected more than 1000 signatures—exceeding the threshold of 10% of the city’s registered voters—to place an anti-BESS measure on the ballot. This measure, approved in November 2024, freezes the current land use designation of Vistra’s proposed site and requires future changes to be approved by a majority of voters, rather than elected officials. (Rode, 2024)

As of late 2024, the draft master plan, which concludes that light industrial uses such as BESS would be compatible with other contemplated uses of the site, was undergoing review by city officials. In addition, the draft environmental impact report, which indicates that building and operating the proposed BESS facility would have minimal impact on the environment or public safety, was being updated in response to the hundreds of comments received. (City of Morro Bay, 2024b) Concerned over voter sentiments and protracted local reviews, Vistra has decided to pursue state-level zoning exemptions and approvals under the provisions of AB205. (Rode, 2024) The developer of a proposed 250 MW BESS facility in the city of San Juan Capistrano is following this path after local officials refused to consider a land use change due to public opposition to the chosen site. (Biss, 2024)

Inter-Agency Fire Safety Working Group (NYFSWG) to help ensure that existing and future grid storage facilities are safe and effective—and that public concerns are addressed. Initial findings demonstrated that the three BESS incidents did not result in reported injuries, harmful levels of toxic emissions, or significant off-site migration of contaminants. (New York State Governor’s Press Office, 2023, 2024)

Guided by national subject-matter expects, the NYFSWG supervised statewide inspection of all operational BESS facilities above 300 kW and developed recommendations addressing preventive measures, emergency responses, and best practices to further improve the regulatory framework for grid-scale BESS (>600 kW) in New York and beyond. (NYFSWG, 2024). Key measures—to be adopted as changes and additions to the *New York Fire Code* or to be advanced or implemented by state agencies—include the following:

- Explosion prevention, fire stop, remote monitoring, video surveillance, alarm monitoring, and safety signage requirements should be expanded.
- The code exemption for facilities owned or operated by utilities should be eliminated.
- Emergency response plans and site-specific training should be required.
- Industry-funded independent peer reviews of complex permitting submittals—such as hazard analysis and mitigation studies—should be required for all BESS installations, as should special inspections.

BOX 5—EMERGENCY & COMMUNITY RESPONSES IN ESCONDIDO, CALIFORNIA

At the 30 MW/120 MWh Escondido BESS owned and operated by San Diego Gas & Electric (SDG&E), emergency response, coordination, notification, and communication plans and procedures developed in accordance with SB38 and other requirements were put to the test after a September 2024 failure. (SDG&E, 2024) The incident involved one of 24 containerized units at the facility, which began operation in 2017 next to an SDG&E substation, maintenance and storage yard, and operations center and surrounded by commercial and industrial buildings.

Responding to an automated alarm, the Escondido Fire Department implemented a defensive strategy to prevent the fire from spreading to adjacent containers. Meanwhile, representatives from city departments, county agencies, and SDG&E collaborated to ensure safety for responders, workers, and the public. A mandatory evacuation order covered buildings around the BESS facility, and the shelter-in-place zone spanned a residential and commercial area extending 2.5 km downwind. However, the Escondido Police Department's emergency notification system issued a broader alert—phone calls were received by residents up to 40 km away. Also, outside the incident command structure, the Escondido Union School District evacuated three schools and cancelled school the next day. (Elmer, 2024).

The fire burned itself out within about 13 hours, and the evacuation order was lifted after about 48 hours. (City of Escondido, 2024a) Initial air quality monitoring by the San Diego County Hazardous Materials Team detected combustion by-products typical of structure fires, at levels well below exposure thresholds. SDG&E's contractors conducted extended air quality monitoring and sampled fire suppression runoff, and analytical results indicated minimal on-site risk to human health and the environment and no offsite risks. (City of Escondido, 2024b; Elmer, 2024)

SDG&E's SB38-compliant plans helped ensure exemplary incident responses by well-prepared professionals, but this incident—aggravated by erroneous alerts and unnecessary precautions—exacerbated existing community concerns about BESS technology. Following on a August 2024 resolution calling for stringent siting and development standards, the Escondido City Council enacted a moratorium on new BESS facilities in October 2024 and extended the ban for up to 1 year in November 2024. (Nelson, 2024)

- Knowledgeable individuals should be available immediately by phone in the event of a BESS fire, with qualified experts available for dispatch within 15 minutes and on scene within four hours.
- Original equipment manufacturers should be required to publicly disclose findings from root cause analyses conducted after battery failure incidents.
- Enhanced guidance should be developed relating to safety-related water supply service requirements and to technology-specific best practices for water use during emergencies.

EMERGING DRIVERS

Strong demand for new BESS capacity is expected to continue for the foreseeable future based on market trends, existing clean energy and climate policy commitments, and future targets announced by governments and industry. According to modeling and analysis by the International Energy Agency (IEA), cumulative global capacity needs to surpass 1 TW by 2030—up from 10 GW at the beginning of this decade—to put the world's energy systems on track toward net zero by 2050. (IEA, 2023) Meeting ambitious targets implies deployment at ever-increasing pace and scale, presumably based on broad public acceptance of the technology.

On the plus side, BESS technology is modular, has high energy density, and is generally considered to be unobtrusive and environmentally benign during normal operations. (EPRI 2020a) This creates the theoretical potential to deploy grid-scale storage facilities virtually anywhere with convenient transmission access, including on compact sites, in urban settings, at aging or decommissioned power generation facilities, and at locations in close proximity to residential, commercial, and other land uses. In the real world, BESS siting poses a complex challenge broadly driven by consumer and grid support needs, offtake opportunities, and additional value creation options under applicable policies and tenders, energy and ancillary service markets, and incentives.

Traditionally, interconnection feasibility and land availability have joined business viability as the three primary determinants of BESS site selection. Permitting feasibility—always an important factor but now encompassing both a clear pathway to regulatory approval and acceptance by the host community—is of growing importance, as indicated in **Figure 5**.

Generally, grid-scale storage is required to be an allowable use of land, meet relevant codes and standards, and comply with construction, environmental, and other permitting requirements. AHJs can range from regional and local officials and boards with varying degrees of responsibility, knowledge, and capacity—and discretion—to state and federal agencies charged with reviewing and permitting utility-scale infrastructure. As a general rule, fire safety agencies and officials are showing growing sophistication regarding BESS technology. Community stakeholders interested in EH&S considerations as well as the potential benefits of BESS can include direct abutters, nearby neighborhoods and land users, taxpayers, ratepayers, political officials, and diverse groups and nongovernmental organizations.

Until recently, the patchwork of siting and permitting frameworks and the ***open book*** and ***direct engagement*** approaches adopted by some developers—bolstered by the emergence and evolution of codes, standards, and best practices—have appeared adequate for enabling storage. The rising tide of community-based opposition and the massive scale of required BESS deployment ahead call this assumption into question. These trends also exacerbate the inherent tension between local control and higher-level governmental purposes and mandates. Clear and consistent regulatory frameworks, informed officials and AHJs, trained fire safety departments, deeper community involvement, and novel approaches for enhancing siting, building acceptance, and streamlining permitting can help in addressing the growing challenges facing BESS developers and investors, grid owners and operators, and other stakeholders. Per Figures 2 and 5, achieving the ***social license*** to operate is becoming an increasingly important factor.

COMMUNITY CONSIDERATIONS

While organized BESS opposition is a relatively new development, the factors complicating siting and permitting of grid-scale storage facilities generally align with the interconnected challenges facing renewable energy technologies. When questions and perceived concerns about possible adverse impacts exceed perceived potential for individual and/or community benefits, obstacles to deployment can arise, constraining progress toward larger goals. According

Figure 5. *Community acceptance is an increasingly important component in BESS facility siting.*

to a study of 53 US utility-scale wind, solar, and geothermal projects opposed and delayed or blocked from 2008-21, social considerations played a key role in the majority of cases. (Susskind *et al.*, 2022) The primary contributors to opposition and the associated barriers to success include some combination among the following:

- Community concerns and mitigation measures relating to actual and perceived impacts on the environment, on health and safety, and on land and property value;
- Institutional issues including actual and perceived process inequities and inadequacies, failures in tribal consultation, and intergovernmental disputes; and
- Impacts of delays, restrictions, and added costs on project financing, revenue production, and overall viability.

A 2023 Lawrence Berkeley National Laboratory (LBL) survey of 123 respondents from 62 US developers indicates that about half of the large-scale wind and solar farms they proposed from 2018 forward have suffered delays—with permitting challenges the most common cause—and about one-third have been cancelled. Local zoning and other ordinances and public opposition join interconnection challenges as the three leading causes of cancelled wind and solar projects, and opposition is becoming more prevalent. While the costs of addressing opposition are increasing, three-quarters of respondents agreed that increased community engagement reduces project cancellation rates, and that public feedback prior to construction can be valuable but should not be determinative, in terms of recommending or making siting decisions. (Nilson *et al*., 2024)

Collectively, responses from project developers who participated in the LBL survey also indicate the following:

- The top 4 public concerns and root causes of clean energy opposition are visual impacts, sound impacts for wind and agricultural land conversion for solar, effects on residential property value, and changes in community character.
- Community feedback most commonly results in modest mitigation measures such as changing vegetation screening for solar and turbine layout for wind, excluding areas from development, increasing setbacks, and providing additional compensation for neighbors.
- In-person meetings with local stakeholders and participation in local government meetings are judged as the most effective among the outreach, education, and engagement strategies surveyed. No approaches were identified as “very effective.” A handful of open response submissions identified local hiring and community-based donations and volunteerism as “particularly effective.”
- Across host communities, the most feasible methods for increasing support and mitigating concerns include additional tax revenues and more generous negotiated payment-in-lieu-of-tax (PILOT) agreements and community benefit agreements (CBA). Enabling community-based ownership and delivering direct energy savings or other benefits to local consumers are viewed as infeasible by developers.
- On average, only 1% of capital expenditures are devoted toward community engagement. Barriers to increased developer investment include budget and time line constraints and uncertain return. Business model, financing, and institutional considerations challenge US implementation of new approaches for delivering community benefits.

A second 2023 LBL survey explored the perceptions and experiences of a nationally representative sample of 984 residents living within about 5 km of large-scale solar projects—from 1 MW up to about 250 MW—deployed from 2017-21. (Rand *et al*., 2024) While the same community-based concerns about grid-scale projects were highlighted

Figure 6. *Renewable energy project developers and residents living near large-scale solar plants offer useful perspectives on building public acceptance for future grid-scale BESS facilities.*

in both surveys, many residents report positive overall attitudes toward operational projects despite perceiving some adverse local impacts. One-third of residential respondents agreed that the public should be involved in recommending or making siting decisions—a more than five-fold increase over the fraction of developers expressing that sentiment. Additionally, residents expressed strong support for local ownership, direct energy savings, job creation, and other community benefits. (Rand *et al*., 2024; Nilson *et al*., 2024)

For community planning and engagement purposes, the insights gained from solar and wind experiences highlight the need for close consideration of the full range of potential concerns, benefits and detriments, and opportunities associated with grid-scale battery storage deployment at specific locations. **Table 1** summarizes general EH&S considerations for energy facilities as related to BESS deployment, operations, and end of life. **Table** 2 details EH&S aspects unique to grid-scale lithium ion battery storage.

Safety is of course the critical issue that must be addressed to the satisfaction of property owners, neighbors, first responders, local officials, AHJs, and host communities. At a bare minimum, fire departments must be confident they can ensure public safety in the event of an incident—and developers may be required to assume the costs of equipping them with the needed capabilities and training. Other local requirements vary by jurisdiction. Members of the public also are concerned about aesthetics, noise, and

Table 1. Conventional EH&S Considerations for Energy Facilities: Grid-Scale Lithium Ion BESS

	EH&S CONSIDERATIONS	IMPACTS & MITIGATION
SITE DEVELOPMENT	Land Use	Grid-scale BESS facilities require land clearing, which can involve habitat loss and forest conversion, but they have a relatively small physical footprint, as compared to fossil or renewable generation, due to the high energy density of lithium ion batteries. Modular, containerized BESS units—generally affixed to concrete pads—are exposed to the environment or enclosed within buildings and served by ancillary equipment, as well as plant-level control and interconnection infrastructure. Site selection, existing site usage and condition, nearby land uses, and receptor proximity influence impacts and mitigation requirements.
	Stormwater Management	Concrete pads create impervious surfaces and potential for concentrated flows. Stormwater management requirements depend on location, existing topography and drainage, and severe weather and climate resilience considerations. Best management practices (BMP) are employed for impact mitigation throughout construction and operations. Remote closure and other features can be integrated to control water applied during BESS failure events.
	Climate Resilience	BESS facilities, like other energy infrastructure, are increasingly subject to climate risk evaluations. BMPs, which include elevating concrete pads and access roadways in floodplains and other areas vulnerable to inundation, are employed for impact mitigation across facility lifetime.
	Construction Activity	Facility construction involves heavy equipment for site preparation and BESS deployment but typically occurs over periods measured in months rather than years. BMPs are employed for impact mitigation throughout the construction phase.
	Visible Aesthetics	As energy infrastructure, BESS facilities present an industrial appearance but have a low profile unless overhead lines are required. Separation distances, vegetation, or other forms of screening—including community-based artwork on walls or building exteriors—can be employed to mitigate impacts to offsite receptors.
OPERATIONS	Air Emissions	No air pollutants or greenhouse gases (GHG) are generated during BESS operations.
	Traffic	BESS facilities have limited impacts on local traffic during operations, as no or minimal onsite staffing is required.
	Noise	Operational noise is limited to the hum of electrical equipment and cooling fans. Separation distances, vegetation screening, and other noise attenuation measures are commonly employed to mitigate BESS impacts for offsite receptors.
	Electric and Magnetic Fields (EMF)	EMFs produced by operational batteries, cables, inverters, substations, and power lines are similar to those generated by other energy infrastructure. Because fields rapidly dissipate away from sources, separation distances and natural attenuation mitigate potential for additional exposures by offsite receptors, beyond background levels.
	Water Use	No water use is required during BESS operations.
	Fuel Use	No fuel inputs are required during BESS operations.
	Chemical Use	No large-scale chemical inputs are required during BESS operations.
	Wastewater	No wastewater is generated during BESS operations.
	Solid Waste	No solid waste is generated during BESS operations.
END OF LIFE	Decommissioning	Depending on lifetime and other factors, BESS facilities may require one or more partial or full battery removal and replacement cycles to offset the impacts of performance degradation. Spent modules are recycled. Decommissioning at end of facility lifetime involves removal and disposition of battery modules, balance-of-plant equipment, and infrastructure, as well as site restoration. Developers and owner/operators can be required to purchase bonds or maintain other forms of financial security in order to provide assurance that BESS facilities will be decommissioned if abandoned or at end of commercial lifetime. (EPRI, 2021a, 2022a, 2023c, 2023d)

Table 2. *EH&S Considerations Unique to Grid-Scale Lithium Ion BESS*

	CONSIDERATIONS, IMPACTS & MITIGATION
Fire Safety	Like many energy systems, lithium ion batteries have inherent hazards mitigated through robust design, careful construction, and proper operation and maintenance. The main concern with grid-scale BESS facilities is the potential for individual cells to experience internal failures and undergo thermal runaway, where stored energy is converted into heat, degrading internal materials, generating additional heat, and causing further degradation. Left uncontrolled, these self-sustaining reactions can rupture external casings and release hot, particle-laden gas. This creates the possibility for failure propagation to neighboring cells and modules and for ignition, fire, and explosion. (EPRI, 2022d) Gaseous releases and other by-products of thermal runaway events, including water applied for fire suppression, can contain toxic constituents. (EPRI, 2022e) Stringent codes and standards and rigorous engineering and controls afford today's large-format cells and modules and containerized BESS products with multiple levels of protection against thermal runaway, failure propagation, and explosion. (EPRI, 2023a, 2024b) To manage risks at individual facilities, HMA, FMEA, and air plume dispersion modeling enable comprehensive assessment of threats, consequences, and potential mitigation measures. (EPRI, 2021b, 2022c, 2024c) Close coordination with local fire departments, public safety officials, and specialty consultants supports the development of multifaceted engineering protections, site-specific emergency preparedness and response plans, and post-incident decommissioning plans, as well as delivery of robust training programs. (EPRI, 2021b) The multilayered combination of preventive measures, precautions, programs, and procedures helps ensure that if a rare failure incident occurs, onsite workers, emergency responders, and the public are not exposed to hazardous conditions or chemicals.
Air Emission Offsets	Grid-scale BESS facilities are commonly deployed and operated to store solar and/or wind energy generated during off-peak periods for discharge and use when demand is higher. Depending on the mix of available system resources, these facilities can help reduce regional emissions of conventional air pollutants and GHGs by displacing fossil-fired peaking units that would otherwise be dispatched. (EPRI, 2020b) Determining anticipated regional emission offsets for proposed BESS facilities requires modeling of charge and discharge cycles and system operations in order to analyze the emission profiles of electricity stored during off-peak periods and of peaking units displaced during battery discharge. (e.g., Industrial Economics Clinic, 2022) Net GHG reductions attributable to BESS operations represent the balance of annual offsets versus annual losses in carbon uptake and storage due to land use conversion. For communities located in the vicinity of displaced fossil-fired units, reductions in annual pollutant emissions can translate into air quality improvements and health benefits.
Battery Materials, Circularity & Sustainability	Like all major energy infrastructure, BESS facilities require the manufacturing, construction, operation, and decommissioning of complex assemblages of materials, components, subsystems, and ancillary equipment. Individual grid-scale installations can incorporate from thousands to millions of large-format battery cells, varying in number based on facility size but also cell chemistry and type. Spent battery cells and modules are transported to recycling plants for disassembly, processing, recovery of valuable materials, and residuals disposal. (EPRI, 2021a, 2022a, 2023c, 2023d) During BESS facility siting and permitting processes, questions commonly arise around the life-cycle impacts and overall sustainability of relying on limited global supplies of lithium and cobalt, other critical materials and minerals deemed essential for national security and economic prosperity, and materials and minerals that may be supplied by sources in regions characterized by conflict or inadequate labor, health, and safety protections. These materials and minerals represent a tiny fraction of the total mass of a grid-scale lithium ion BESS, and they can be recovered at end of life. While upstream extraction and processing, cell and module manufacturing, and construction do contribute about 90% of lifetime GHG emissions, estimated life-cycle emissions are 33 g CO_{2e}/kWh. (US National Renewable Energy Laboratory, 2021) This is roughly 15 to 30 times lower than gas-, oil-, and coal-fired power plants and does not account for grid-level emission reductions often attributable to BESS operations. Circularity standards specific to large-format battery cells do not exist, but battery suppliers and system integrators can be encouraged or required to provide data, disclosure statements, and product declarations addressing raw materials sourcing, cell and module composition, and recyclability. (EPRI, 2021a) According to EPRI's recent assessment, global efforts to increase extraction, improve the reliability of supply, and diversify supply chains—including through use of materials recovered from spent batteries—are likely to mitigate the potential for resource scarcity and long-term shortages in material availability. (EPRI, 2024e)

home values, and they are interested in fewer power outages, lower energy bills, fair treatment, and many other factors that shape daily existence.

Figure 7 characterizes potential community benefits specific to the energy-related services available from grid-scale BESS facilities, building on EPRI's review of opportunities in the areas of workforce and job training, student and community education, economic development, environmental justice, and diversity, equity, inclusion, and accessibility. (EPRI, 2024d)

SOCIAL LICENSE

Recent experiences with grid-scale BESS are consistent with historical precedents in energy and other industries: Innovations in technology and practice, proactive communication leading to improved understanding, compliance with regulations and other institutional frameworks, and permit approvals are not always sufficient to achieve public acceptance for projects in specific locations or regions. Achieving a social license to operate is contingent on the beliefs, opinions, and perceptions of the community. (Otway *et al*., 1978; Gunningham *et al*., 2004; Hoedl, 2021, 2023; Thomson & Boutilier, 2020)

According to the social license approach, securing community consent for BESS facilities should involve a process of building trust with local stakeholders on the basis of demonstrated commitments to transparency, broad and meaningful engagement, community benefits, and risk reduction leading to health and safety protection. Ideally, two-way dialogue begins before a specific site is selected, involves traditionally marginalized and under-represented groups, and starts from a broad context addressing the issues local people are actually concerned about and interested in, rather than the ones identified by project developers and their consultants.

By de-conflicting the process of site selection, developers and community members have the opportunity to learn from each other and work together in shaping a shared project narrative that is more about benefits to be realized from hosting a BESS facility than about mitigating potential for adverse impacts. This can allow for more fulsome consideration of the possible benefits of BESS generally and of potential sites specifically—and identification of new opportunities for creating value. It also can provide a sense of procedural justice, even for opponents of a proposed facility or particular site. (Ottinger, 2013) However, defin-

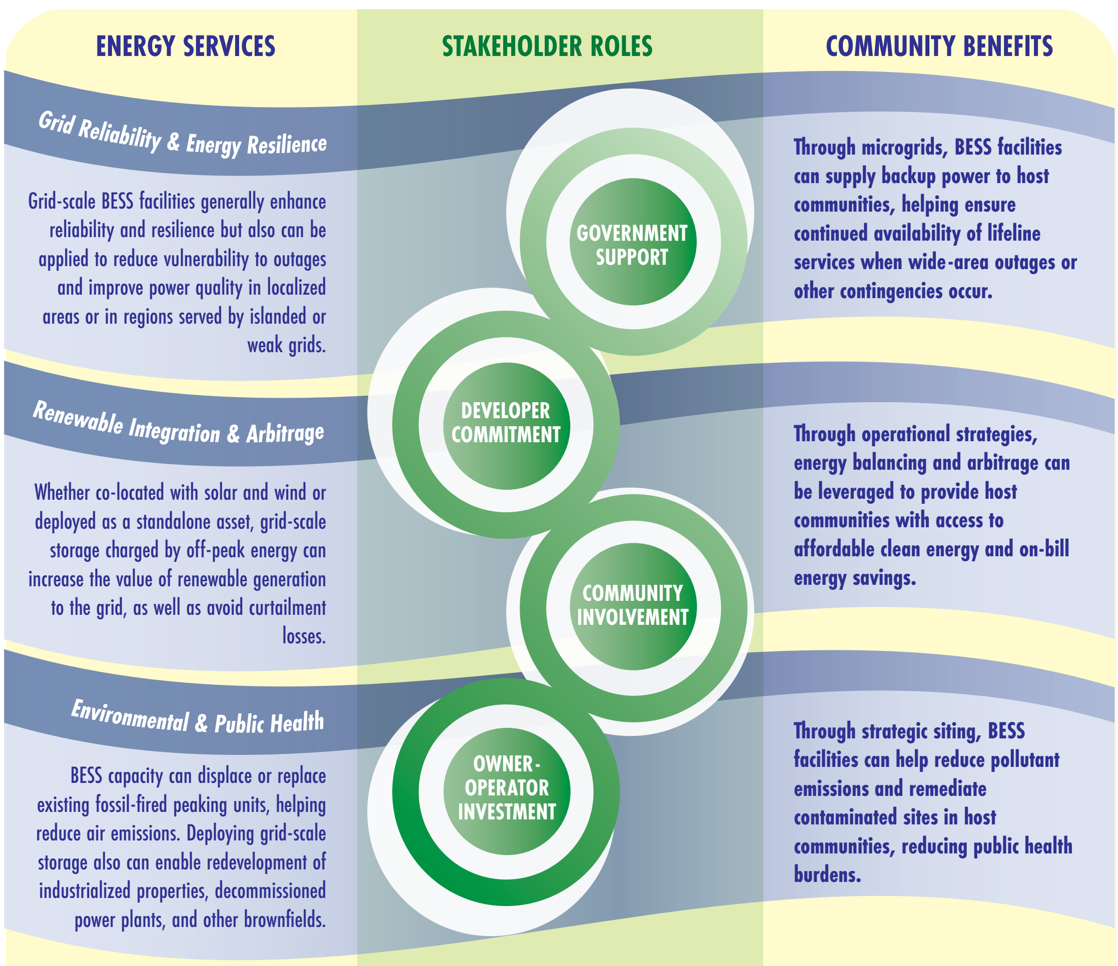

Figure 7*. Grid-scale BESS facilities have potential to deliver direct energy-related services to host communities, assuming key stakeholders make progress in aligning incentives and sharing benefits.*

ing community benefits can add uncertainty, time, and cost to the early stages of project development. The terms of negotiated CBAs also can increase all-in deployment costs and reduce net revenues during operation.

Under New York's Accelerated Renewable Energy Growth and Community Benefit Act of 2020, developers of BESS facilities proposed in conjunction with renewable generation projects larger than 25 MW are required to deliver benefits beyond tax revenues, as well as provide funding to assist host communities in participating in state-level siting and permitting processes and in securing tangible benefits through executed CBAs. (Niagara Frontier Publications, 2020) Some US Department of Energy (DOE) funding programs supporting BESS deployment require applicants to submit community benefit plans, including the "Energy Storage for Social Equity" (ES4SE) initiative launched in 2021 and a number of grant opportunities under the US Infrastructure Investment & Jobs Act and Inflation Reduction Act. (EPRI, 2024d)

IMPLICATIONS & NEXT STEPS

Grid-scale battery storage is important for supporting the energy transition, increasing the reliability and resilience of electricity infrastructure, and delivering localized benefits to host communities. Like US solar and wind farms, battery storage facilities are experiencing longer development timelines—doubling in some instances—and higher siting and permitting costs, along with high rates of project cancellation. Factors contributing to delay at specific sites include typical proximity and community character issues in combination with technology-specific considerations, notably novelty, the lack of clear and consistent regulatory frameworks, and the emergence of fire safety concerns and political polarization as fuel for organized opposition.

In a growing number of instances, individuals and community groups are taking initiative to prevent grid-scale storage projects from being built by influencing the decisions of local officials, supporting municipal adoption of restrictive zoning regulations or outright bans, and developing and campaigning for targeted referendums. At the same time, state decision-makers charged with meeting energy and emission goals are creating pathways to enable BESS deployment by superseding local control over siting and permitting, as well as new opportunities for communities to have a greater voice in the process—and potentially a larger share of the available benefits.

Expanding markets are attracting new developers and different types of organizations, creating competitive pressures and the potential for mistakes or shortcuts in an environment where individual failures have industrywide implications. Failure prevention, risk reduction, and incident management actions to date by cell and battery manufacturers, system integrators, project developers, owner/operators, and government entities continue to be critical, but they are not enough.

Government agencies and officials have several important roles to play. First, they can ensure that existing grid-scale lithium ion battery storage systems undergo comprehensive safety inspections, that independent root cause analyses are conducted after BESS incidents, and that findings and recommendations are proactively communicated across host communities and to key stakeholder groups. They also can evaluate existing code, siting, and permitting frameworks for standalone grid-scale storage facilities and renewable-plus projects, look to models applied elsewhere for ensuring BESS safety while accelerating deployment, and create clear and consistent pathways for AHJ approvals at both state and local levels. The key is to find the right balance between community concerns and benefits and the higher-level mandates contingent on rapid rates of BESS deployment.

Agencies and officials also need to work with grid regulators, independent system operators, and utilities to quantify and document the value of battery storage for meeting reliability, resilience, renewable energy, and emission reduction goals and then to create effective markets, procurement processes, and compensation mechanisms. If BESS owners and operators can access the full range of energy, capacity, and ancillary service opportunities created by storage facilities interconnecting at specific locations, then reduced uncertainty and the potential for increased overall revenues can empower developers to allocate additional resources for community engagement and delivery of tangible benefits through CBAs.

Credible sources of information on grid-scale BESS facilities are needed to help inform AHJs and the public, as well as dispel misconceptions. According to LBL's survey

Figure 8. *Community-based dialogue is essential in building trust and creating social license for BESS facility siting and operations.*

of neighbors of large-scale solar projects, nonprofit energy organizations and people who live near existing projects are viewed as the most trustworthy sources for information on proposed energy facilities, followed by community organizations and universities. The least trusted entities are federal and state officials, followed by project developers, local officials, and news reporters. Local electric utilities fall somewhere in the middle. (Rand *et al*., 2024)

These findings suggest that non-partisan organizations like EPRI have the opportunity to act as honest brokers of BESS-related information, addressing both real-world safety experiences and best practices, along with potential benefits for the grid and host communities. AHJ-focused education is particularly important in helping ensure that policies, regulations, and review processes relating to land use and permitting are effective in accommodating BESS facilities at appropriate locations while also holding developers, owners, and operators accountable for ensuring public safety and addressing other community considerations.

BESS developers and energy providers involved in developing or procuring storage capacity need to place more emphasis on community acceptance. The theoretical ability to site BESS practically anywhere with transmission access is now tempered by the reality that proximity to residential areas, schools, hospitals, recreational amenities, and other gathering places can engender strong opposition. Public acceptance and community benefit considerations need additional weight during site selection, including through government and utility solicitations and through procurements aimed at fostering storage capacity additions.

Rural areas, large properties, industrial zones, brownfields, and areas near waste management, wastewater treatment, energy, and other infrastructure and industry can provide opportunities to site storage facilities at locations remote from sensitive receptors. As highlighted in Figure 7, BESS facilities also can be sited and developed to directly address host community needs, such as by reducing outages, improving resilience to severe weather, and providing energy savings to underserved populations and groups. Deploying storage to reduce regional reliance on peaking units or to repower aging or retiring fossil power plants has potential to localize environmental benefits. BESS capacity sited at operational assets or decommissioned sites has the added advantage of improving grid reliability without requiring new transmission lines.

Comprehensive consideration of BESS approval pathways is essential, especially when alternatives exist. County, city, and town officials are generally accommodating when opportunities for new revenues arise, especially when promised pros exceed perceived cons. With grid-scale storage more likely to face vocal local opposition, developers and owner/operators can benefit from asking themselves, "What will it take to get this facility approved and built?"—and then applying a holistic perspective in building relationships in host communities, including with AHJs.

Avoiding conflict is a key consideration. Some municipal officials may prefer state-level siting and permitting as means of moving forward with a BESS project they deem to be in the best interest of their community. However, if facilities are granted exemptions from local zoning, citizens and officials lamenting the loss of control have opportunities to create obstacles and additional delays involving road crossings, water supply connections, occupancy permits, and other purely local processes. The challenge is to find a balance between local buy-in and timely progress.

Outreach to and engagement with potential host communities should begin before a specific project development opportunity is conceived—and prior to site selection. Relationship-building starts by finding common interests, both independent of energy storage and on BESS in general. In addition to increasing revenues through property taxes, point-of-sale agreements, and PILOT agreements, issues such as investing in local economies, supporting clean energy, creating jobs, improving resilience, addressing inequities, and building community can have broad resonance plus specific relevance. Even if projects are somewhat further along in development, achieving social license begins with conversations around community needs and aspirationsxs to create space for introducing grid-scale storage as a local opportunity. Outreach launched just prior to seeking siting and permitting approvals is too late.

Telling a story emphasizing community benefits is the recommended starting point, rather than the traditional approach of disseminating facts about BESS facilities and fire safety assurances as the precursor toward discussing candidate sites. This can mitigate the need to counter misinformation and the potential for emotional responses. Intentional stakeholder and community outreach is critical to ensure that the right people are brought into public dialogue, as one effective voice can be determinative, in either direction.

Review of news, social media, community, government, and other online resources—current, recent, and historical, depending on context—can help in identifying trusted individuals, respected local groups and officials, other influencers, and natural and prospective allies. Representatives of traditionally disadvantaged populations and tribal organizations should be included from the initiation of discussion. Support from national or state-level environmental and labor organizations can be useful but also can be perceived as outside interference.

Experience demonstrates that local political and administrative officials are attracted by new sources of revenue but can be swayed in the face of BESS opposition—and that other community benefit considerations can provide the basis for creative partnerships. Public safety officials are highly respected, increasingly knowledgeable about BESS, and can be effective advocates, even indirectly. Fire departments and communities at large can benefit from assurances that the expenses required to ensure safety—for planning, training, and equipment and for adequate water supply in the event of an emergency—will be shared by the developer and owner/operator. Real-world examples include expansion and extension of existing water supply districts and infrastructure, provision of reliable onsite supply via the drilling of new wells or the construction of storage tanks, and the addition of freeze protection, emergency generator, and other systems.

Because a lack of information creates a void which misinformation often fills, developers hosting community meetings should be prepared to answer safety-related questions in terms the general public can understand—and post-event follow-up to any unanswered questions should be immediate and publicly accessible. Similarly, specifications, plans, drawings, and other information needed by fire departments should be available before requests are received in order to demonstrate attention to safety considerations and code requirements.

Community benefit opportunities specific to grid-scale BESS require further development. Battery storage facilities can deliver grid reliability, energy resilience, renewable energy integration, energy arbitrage, and emission reduction services, producing revenue and additional value for owner/operators and society as highlighted in Figure 7. In the LBL surveys, project developers identified community-based ownership and energy savings for local consumers as infeasible, while residents living near large solar energy projects preferred these direct energy-related benefits.

To help bridge this gap, potential follow-on EPRI research topics include deeper examination of possible approaches to deliver community benefits intrinsic to BESS technology—for example, by applying ownership, subscription, aggregation, on-bill savings, and additional business models that have succeeded in renewable energy applications. Lessons learned from experiences elsewhere can be leveraged in combination with US Inflation Reduction Act provisions that allow municipalities, states, tribal governments, nonprofits, and other organizations to take advantage of tax credits in support of direct community energy benefits.

Additional possible EPRI research topics include (1) surveying developers, AHJs, host community representatives, and other stakeholders on how BESS knowledge, characteristics, and perceptions can influence siting and permitting processes; (2) conducting social license case studies for BESS facility siting and CBA development; and (3) developing a roadmap for leveraging EPRI's knowledge base, capabilities, and connections to develop resources that assist all stakeholders in advancing BESS understanding and site-specific deployment.

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3002031624 February 2025

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