Mobile Energy Storage Study

Emergency Response and Demand Reduction

Executive Summary

Massachusetts Department of Energy Resources

February 1, 2020

DOER

Massachusetts Department of Energy Resources

Acknowledgments

On August 9, 2018 Governor Baker signed *An Act to Advance Clean Energy* (the Act) into law. Section 22 of the Act directed the Department of Energy Resources (DOER) to study the feasibility of mobile battery storage systems to respond to extreme weather events or power outages and provide emergency relief.

DOER Commissioner Patrick Woodcock would like to acknowledge the following people for their assistance in the analysis and drafting of this report.

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EXECUTIVE SUMMARY

Strategic electrification of transportation and thermal loads is necessary to achieve the State's emissions goals; however, they increase our dependence on constant access to electricity. As a result, the impacts of outages increase with electrification and at a time when the effects of climate change increase the likelihood of major disruption events driving a need for further energy resilience.

Methods to increase the resilience of our electric system and enhance our emergency response capabilities is a core adaptation strategy to align with our electrification strategies. Energy storage is widely recognized for its ability to enhance energy resilience. Battery energy storage systems (BESS) increase resilience by providing local electric service through an outage, extending the run-time of emergency generators by increasing efficiency and reducing fuel consumption, and enabling renewable generators to produce power through outages.

Most BESS solutions are stationary, interconnected with permanent infrastructure and designed to serve localized loads. BESS have a long history of serving this role in the form of Uninterruptable Power Supplies (UPS), often found in data centers and locations negatively impacted by even short duration power disruptions. Resilient BESS solutions have recently expanded in adoption, often providing backup power paired with renewable generation in residential applications. This report is designed to analyze an alternative, in which energy storage solutions are mobile and can be physically dispatched to prioritized locations based upon evolving emergency response needs and thereby expanding the resilience of a broader range of facilities.

Study Overview

On August 9, 2018 Governor Baker signed An Act to Advance Clean Energy (the Act) into law. Section 22 of the Act directed the Department of Energy Resources (DOER) to study the feasibility of mobile battery storage systems to respond to extreme weather events or power outages and provide emergency relief.

Further, on September 16, 2016 Governor Baker Signed Executive Order No. 569: Establishing an Integrated Climate Change Strategy for the Commonwealth.[1] In 2018 Massachusetts became the first state in the nation to integrate climate change impacts and adaptation strategies into its hazard mitigation planning through the Statewide Hazard Mitigation and Climate Adaptation Plan.[2]

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[1] Executive Order No. 569: Establishing an Integrated Climate Change Strategy for the Commonwealth available at https://www.mass.gov/executive-orders/no-569-establishing-an-integrated-climate-change-strategy-for-the-commonwealth

[2] Statewide Hazard Mitigation and Climate Adaptation Plan available at www.resilientma.org

Massachusetts is developing data-driven strategies to mitigate, prepare for, and adapt to the impacts of climate change. Climate change is already exacerbating natural hazards and extreme weather events, as well as leading to new impacts that will affect the Commonwealth.

The 2016 Massachusetts Energy Storage Initiative Study, known as the *State of Charge* report, found that:

> "Storage provides energy resilience allowing critical facilities and other loads within the microgrid to ride through prolonged grid outages, maximally leverage renewable resources (such as solar PV), and/or extend limited liquid fossil fuel supplies."[3]

Mobile energy storage systems (mobile ESS) may be uniquely capable of enhancing energy resilience in response to severe weather events and associated outage conditions. Mobile ESS can be self-mobile electric vehicles (light-duty vehicles, vans, or buses) or towable (towable or transportable via semi-trailer truck). This study provides a comprehensive assessment of Mobile ESS, their use in emergency relief operations, and their use on typical (non-outage) days. Specifically, this report addresses four fundamental questions; state-of-the-art, usage on typical days, opportunities and challenges to deploy in response to outages, and potential advantages over stationary BESS.

Key Findings and Takeaways

State-of-the-art

- **Mobile ESS products can be categorized into self-mobile such as electric vehicles (EVs) and towable such as shipping containers**

Self-mobile ESS ranges from light duty vehicles to transit buses, with an anticipated future inclusion of heavy-duty trucks. Towable mobile ESS are often containerized solutions ranging from human-portable to standard 53' shipping container sizes.

- **Mobile ESS can provide valuable emergency relief services, and offset procurement costs with operations on typical days**

The ability for mobile ESS to provide service on typical days enables a return-on-investment, which is atypical in the realm of emergency response equipment. Additionally, mobile ESS can improve emergency response services and capabilities beyond traditional emergency response equipment such as diesel generators.

- **Self-mobile ESS adoption is accelerating to meet transportation needs, however the batteries are currently under-utilized when parked and in emergency situations**

Light duty EV adoption is increasing exponentially. To-date, the batteries of light duty EVs have been solely used for transportation needs. Pilot projects have demonstrated vehicle-to-grid opportunities,

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[3] Massachusetts Department of Energy Resources and Mass Clean Energy Center. 2016. State of Charge: for a study of Energy Storage uses in Massachusetts Energy Storage Initiative, Page 131. Available at https://www.mass.gov/media/6441/download

and in recent broad outage conditions EV owners have leveraged their EV battery to power their home by driving beyond the extent of the outage, charging, then returning home to power onsite load.[4]

- **Self-mobile ESS may provide customers energy distribution services**

EVs have substantial flexibility in the time of charging, as many vehicles have around 200 miles of range but drive an average of less than 35 miles per day. The substantial oversize of onboard energy capabilities compared to typical daily use means the battery could be leveraged to wirelessly distribute energy over-road to serve customer load. For example, if a residence has stationary storage, the EV could potentially charge the household battery, reducing or mitigating the customers' reliance on local distribution service in both typical days as well as through outage conditions. This pathway further opens as buildings become more efficient, workplaces increase the offering of EV charging as an employee benefit, retail sites offer EV charging as a customer benefit, retail package delivery and transportation service providers independently move to electrify their fleets, and solar canopy deployment continues. Depending on the cost of charging off-site, the pathway also provides further customer incentives to electrify transportation and thermal loads.

- **Self-mobile ESS may open substantial renewable energy transition pathways**

Self-mobile energy storage may enable the deployment of renewable generation which is not interconnected with the grid. As distributed generation increases, the system increasingly requires substantial expensive infrastructure upgrades to host more renewable generation. Solar PV deployment has traditionally relied on export to the grid (e.g. Net Metering) to make sense financially and this may not continue to be possible without infrastructure upgrades. To resolve this, on-site stationary storage would need to be substantially oversized in order to island and store renewable generation for later consumption, a potentially inefficient investment. Self-mobile energy storage in the form of EVs may provide an opportunity to charge from otherwise excess renewable generation and enable the deployment of renewable generation that is not dependent on export to the grid, thereby mitigating the costs associated with interconnection upgrades. Further, since the typical daily transportation needs of an EV are low compared to the onboard storage capacity, the EV can provide transportation without charging every day, enabling charging to align with renewable production, reducing or skipping recharging on cloudy or overcast days. This would shift demand to align with available generation.

- **Autonomous self-mobile ESS opens additional business models**

Autonomous self-mobile ESS opens the opportunity to merge the concepts of transportation as a service (TaaS) with energy as a service (EaaS) into a bundled subscription and delivery of utilities provided by a single physical fleet. A fleet operator would leverage the EV fleet to provide transportation services, while also distributing electricity over roadways to recharge stationary energy storage systems at customer sites. This service would make the energy transition seamless and invisible to the customer,

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[4] 'With Blackouts, California's Electric Car Owners Are Finding New Ways To Charge Up.' Vanessa Romo, NPR, December 11, 2019. https://www.npr.org/2019/11/08/777752175/with-blackouts-californias-electric-car-owners-are-finding-new-ways-to-charge-up

reducing friction points to adoption. The fleet is also flexible on charge location, so may mitigate constraints and leverage daily and seasonal variations in renewable generation, for example driving to points with access to excess solar generation in spring and to points with access to excess hydro or wind during other periods. Finally, the bundling of TaaS with EaaS provides a substantial increase in addressable market for EV fleets, increasing business opportunities without increasing capital costs, potentially accelerating the electrification of transportation while also enabling novel emergency response approaches and capabilities.

- **Towable mobile ESS is being adopted, but at a slower rate than self-mobile ESS**

Towable mobile ESS has been adopted to-a-degree in the consumer arena in the form of battery backups for laptops and mobile devices. Towable mobile ESS has also been leveraged by remote energy intensive operations (such as mining and military operations) to reduce generator fuel consumption to relieve associated logistics and costs.[5]

Typical day use cases

- **Self-mobile ESS initially operates primarily to provide transportation service on typical days (current use)**

Today, most self-mobile ESS provide only transportation services on typical days. There is currently relatively limited deployment (as compared to traditional fuel-based vehicles), but with ongoing cost declines, EVs are anticipated to be cost competitive on a transportation only basis in the next few years. This will allow for rapid, wide-spread deployment.

- **Self-mobile ESS could provide transportation and distribution on typical days (in the near-term future)**

In this case, the EV provides the owner with both transportation and electric distribution services daily. One operational form of this would be: the EV is driven to work, charged at the workplace (residential stationary storage with or without on-site renewables serve electric load of household while unoccupied), driven home, then discharges to power the home for the evening and overnight and charges the stationary storage (if it wasn't charged by onsite renewables). Depending on the cost to charge the EV, this model may substantially increase customer cost effectiveness of transitioning to an EV. This model would also increase the cost effectiveness of electrifying the customers' thermal loads, as the electricity is subsidized by either work or retail market competition.

- **Self-mobile ESS may operate to provide TaaS and EaaS if full autonomy is realized (in the future)**

[5] 'Decarbonization Takes Center Stage in Mining as Renewables-Plus-Storage Become Cost-Competitive.' GTM CREATIVE STRATEGIES, GreenTech Media, December 30,2019. https://www.greentechmedia.com/articles/read/decarbonization-takes-center-stage-in-mining

The EV is owned and operated by a third-party fleet manager and provides transportation and energy (and potentially package delivery) as subscription services. The EV operates like the above, however the EV may leave when the residence has sufficient onsite charge and the EV would provide better value being elsewhere either charging, providing transportation, or discharging and providing energy services for other subscribers. The transportation and energy service package could be further bundled with retail package delivery given the prevalence of vehicles and fleets currently providing that service and overlap of delivery needs under this model with current delivery behavior.

- **Towable mobile ESS operates to reduce demand charges and local grid constraints**

Typical day use of towable mobile ESS matches typical current stationary storage use cases, with the increased benefit of flexibility to change location based upon seasonal needs or changing grid or customer conditions. Use cases are typically categorized into front-of-the-meter (FTM) grid services and behind-the-meter (BTM) applications. The revenue potential or value streams that energy storage provides generally fall into three broad categories: wholesale, utility, and host customer.[6,7] Wholesale and utility value streams are typically derived from FTM applications, although aggregated BTM systems can also provide these services.

Emergency response use cases

- **Self-mobile ESS currently operate primarily to minimize use of limited fuel supplies and supplement traditional fuel-based generators**

Today, self-mobile ESS can provide transportation and supply delivery services during emergency response outage conditions without using traditional fuel which may be limited in supply and/or re-fueling. With ongoing deployment of V2G infrastructure, self-mobile ESS can more readily participate in emergency response as a back-up energy source operating on its own or in conjunction with traditional fuel-based generators.

- **Self-mobile and towable ESS could harvest energy from stranded distributed sources of generation**

Both self-mobile and towable ESS could be used to transport energy from an available energy resource to an area of an outage. Mobile ESS can move outside of an outage area, charge, and then travel back into an outage area and deliver energy to a facility or provide for transportation needs of personnel or supplies. Energy generation assets that might otherwise be stranded due to downed wires or damaged electric distribution infrastructure can be incorporated into emergency response plans and utilized through an outage.

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[6] Rocky Mountain Institute (RMI). *The Economics of Battery Energy Storage*. October 2015. Available at: https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf.

[7] Lazard. Levelized Cost of Storage Analysis – Version 5.0. November 2019. Available at: https://www.lazard.com/media/451087/lazards-levelized-cost-of-storage-version-50-vf.pdf.

- **Self-mobile and towable ESS could be deployed to form microgrids reducing the impact of long-term outages across a region**

Both self-mobile and towable ESS could be used to form a microgrid at a facility or set of facilities with required infrastructure in place. For example, an emergency shelter could have V2G infrastructure[8] installed in preparation of receiving power from a mobile ESS during an outage. The mobile ESS could connect to and charge stationary ESS and supplement on-site renewable or other generation. If the appropriate wiring and infrastructure were installed to connect that shelter to a neighboring medical or public safety (police or firehouse, for example) facility, that set of buildings could separately island from the grid, provide necessary power to support emergency response needs and serve a broad set of people and their needs through an outage.

Opportunities and Challenges

Mobile ESS provides the opportunity to;

- relieve emergency responders of delivered fuels logistics challenges in emergencies
- enable otherwise stranded generation to produce power
- enable emergency response equipment to provide typical day services
- diversify transportation fuels
- reduce single point of failure reliance on local electric distribution, and
- increase adoption of and dependence on intermittent renewable generation

The adoption of mobile ESS faces several challenges, including;

- operational considerations of disconnecting from typical day usage
- deployment logistical challenges
- interconnection processes including timelines and costs
- interoperability with site generators and loads
- emergency responder training on setup and operations, and
- necessary planning and matching system capability with emergency needs

Advantages over stationary storage

The primary advantage of mobile ESS is the flexibility they provide when deployed in both typical day use and outage conditions. During typical day use conditions, mobile ESS can serve many of the same applications served today by stationary systems. The flexibility offered by mobile ESS provides advantages due to the ability to relocate the mobile ESS as conditions on the grid change over time.

The flexibility of mobile ESS is also an advantage during outage conditions. The nature of many outage conditions—such as those caused by unplanned equipment failure, natural disasters, or terrorism events—is that they cannot be anticipated. Mobile ESS can be deployed to the exact location of the need for emergency power. Paired with traditional, fuel-based generators, mobile ESS can improve the efficacy

[8] This technology is currently available: https://www.mobilityhouse.com/int_en/vehicle-to-grid; https://wallbox.com/en_us/quasar-dc-charger

of generators used for emergency response operations and reduce the cost and frequency of refueling. Furthermore, mobile ESS can harvest energy from stranded distributed sources of generation, including wind farms and rooftop solar. During a prolonged grid outage, this creates a significant advantage through the continued supply of power to critical loads using the grid-forming capabilities that mobile ESS offer.

Mobile ESS create an additional advantage by providing mobility during outage conditions when there is risk of disruption to diesel and gasoline supply. Grid outages during emergency events can lead to downed power lines, which can often be restored quickly. However, disruptions to conventional gasoline and diesel fuel supplies can take longer to restore. Having access to transportation that doesn't rely on conventional fuels can be a valuable asset to disaster relief crews by increasing their flexibility and ability to respond in different situations.[9] The ability to transport personnel and supplies during outage conditions can be critical. As mentioned above, mobile ESS used to harvest energy from stranded DG sources could potentially offer continued mobility services during prolonged outage conditions.

Finally, mobile ESS offer economic advantages over stationary ESS. Emergency response planning includes investments in equipment infrequently used, except during outage conditions. The ability to create value during typical day use conditions serves to offset the initial capital investment. In addition, the capital cost of mobile ESS is largely justified by the mobility services provided during typical day use conditions. A municipal agency that purchases vehicles might consider buying an electric vehicle with V2G capabilities, thus offering the option to deploy the vehicle during outage conditions as part of an overall emergency response plan. The California investor-owned utility Pacific Gas & Electric purchased purpose-built plug-in hybrid trucks that are equipped and designed with the capability to export power. The utility deployed these trucks in October 2015 to power an emergency shelter during a power outage caused by wildfires.[10] In 2011, EVs played an important role when gasoline supplies for conventional vehicles were disrupted; they delivered critical supplies to regions in northeastern Japan ravaged by a tsunami.[11]

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[9] The National Association of State Energy Officials. June 2016. Electric Vehicles and Emergency Response. Available at https://naseo.org/data/sites/1/documents/publications/iREV%20EV%20Case%20Study.pdf.

[10] ibid

[11] After Disaster Hit Japan, Electric Cars Stepped Up. May 6, 2011. New York Times. Available at https://www.nytimes.com/2011/05/08/automobiles/08JAPAN.html.