The Commonwealth of Massachusetts has begun to be a forward-thinking leader in energy storage. Energy storage holds immense potential for the Massachusetts economy, particularly connected to academic research and startup industries, and holds special potential when considering Massachusetts' goal of a grid that provides reliable, low-cost, and sustainable energy. However, there is still much work to do to support the energy storage industry in the development of next-generation battery technology.

Please accept this letter as the report of the special legislative commission as established in Section 134 of Chapter 47 of the Acts of 2017. The commission was charged with studying the feasibility, administration, and economic impact of a battery testing facility, while seeking input and involvement from various public and private entities in the state with expertise or capacity related to battery technologies, clean energy, manufacturing, or engineering.

The commission has convened several times in person and communicated electronically. During the course of the commission's discussions, work was delegated so as to come to an initial finding of what directions would be useful for the legislature and agencies to pursue, before the report submission deadline of February 1, 2018.

To that end, the Massachusetts Clean Energy Center composed and distributed a survey, which was intended to gather input from a cross section of battery-related stakeholders including utilities, universities, industry professionals, and start-up as well as established companies. The University of Massachusetts Amherst's Clean Energy Extension executed a benchmarking study and prepared a corresponding report. The study sought to identify all the existing battery-capable test facilities in the United States which are open for use by companies and researchers. The report provides a foundation to better understand the range of existing test facilities, who they serve, and how they operate. The commission is grateful for the input from all of the stakeholders who engaged in these processes and would like to sincerely thank them for both their time and their expertise.

Attached are summarized results of the survey conducted by the Massachusetts Clean Energy Center and the final benchmarking report created by UMass Amherst students and faculty. The general takeaway is that there may be diffuse gaps in the battery technology development ecosystem and infrastructure, but that there is not unified and specific interest by existing stakeholders in any single new battery testing site. However, several issues were identified by stakeholders as obstacles to storage industry development, some of which had to do with accessing existing facilities, and most of which were associated with the need for state policy and investments to develop a market environment that is favorable for storage company scale-up.

While *existing* industry indicated that creating a new testing facility in Massachusetts is not a priority need at this time, some survey participants expressed strong interest, and in other meetings it has been suggested that *emerging* industry players would find such a facility useful. In particular, it would be valuable to pursue public and private partnerships with institutions that have integrated microgrids that could serve as a location for energy storage startups to demonstrate the efficiency and performance of technologies.

Existing industry indicated that, for them, the barrier to testing is not the availability of testing equipment, but the ability to access that existing testing equipment. Thus, the commission looked at how to best assist companies in accessing these existing resources, such as the facilities identified in the benchmarking study, many of which are outside Massachusetts. The commission also gave thought to ways the state could help companies access distributed university laboratory equipment across the Commonwealth. Through further conversations, members of this commission will identify better ways to publicize existing testing and laboratory equipment, including a potential online database wherein university laboratory testing equipment could be posted for rent and where companies could search for available equipment to rent time on.

The commission found that the industry could potentially benefit from financial assistance programs, such as matching fund and voucher programs, to Massachusetts-based energy storage innovators to increase access to state-of-the-art university facilities with testing equipment as well as out-of-state facilities, to support their storage technology development and testing efforts. Matching funds can be low-risk for the Commonwealth because they go to companies that have already been vetted by private investors or Federal government agencies. The Clean Energy Center and the Massachusetts Department of Energy Resources are already engaged in some such programs, including the Advancing Commonwealth Energy Storage (ACES) grant program for energy storage demonstration projects that pilot innovative, broadly replicable energy storage use cases/business models with multiple value streams in order to prime Massachusetts for increased commercialization and deployment of storage technologies, the InnovateMass and AmplifyMass investment programs which help companies overcome barriers to initial development, and the storage incentives in the new Solar Massachusetts Renewable Target program for solar deployment. As these programs approach completion, additional funding or programmatic changes will be evaluated to ensure that Massachusetts continue to support the deployment of energy storage in the Commonwealth. Particularly, the commission recommends exploring the feasibility of providing vouchers to companies seeking to test their storage technologies at test facilities or in university labs.

The Clean Energy Center and Department of Energy Resources plan to continue building off of their existing programs by continuing to invest resources in new storage technology research and development, prototyping, monitoring and reporting on the outcome of storage demonstration projects already funded by the state, which will help inform policy and identify market barriers to storage deployment; and exploring opportunities to reduce storage permitting barriers as well as potential investments in safety best practices and training.

The commission looks forward to continuing analysis as directed in the FY2018 budget. Further study will analyze opportunities to leverage existing laboratory and testing facilities to catalyze energy storage technology development for both existing and emerging industry. The commission recognizes that there is a significant opportunity for policy to advance energy storage technology development and deployment in Massachusetts and hopes that the commission's work and this study will expedite this development.

Representative Solomon Goldstein-Rose
House Commission Chair

Senator Eric Lesser
Senate Commission Chair

Energy Storage and Battery Test Facilities:
National Benchmarking Report

Prepared for:

Special Legislative Committee
(Established pursuant to Section 134 in Chapter 47 in the Acts of 2017)

January 2018

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Executive Summary

This report outlines a preliminary benchmarking study conducted for the special legislative commission as established in Section 134 in Chapter 47 in the Acts of 2017 (herein referred to as the Commission) with the intent of identifying and describing test facilities for potential grid-integrated energy storage technologies. The scope of the study includes test facilities designed to advance the design of new battery cell technologies, as well as facilities designed to advance new battery systems towards commercially viable products. We found thirteen (13) test facilities, of which five (5) operate in association with a university, six (6) operate as national laboratories within the U.S. Department of Energy, and two (2) operate otherwise within the federal government or as a private entity. The benchmarking of these facilities is provided in Table 1.

The university-based facilities generally focus on testing pilot-scale cell prototypes and/or prototype systems closer to commercialization. These labs were generally served industry, entrepreneurs or researchers using a membership and/or fee-for-service model.

The DOE-supported National Laboratories focus on early-stage research of novel technologies, rarely venturing beyond pilot-scale proofs-of-concept. They assist small private businesses, but these collaborations are more likely to require applications to programs and grants as opposed to an open fee-for-service model.

Between these university and national lab based facilities, a potential gap was identified in transitioning energy-storage technology from pilot-scale prototypes to pre-commercialized systems. The identified test facilities are scattered geographically around the U.S., as shown in Figure 1.

This benchmarking scope was limited in time and resources, but provides a platform for further investigation by the Commission to more fully assess energy storage test facilities in the U.S. and opportunities for Massachusetts to advance a new test facility to support and attract technology innovation and business development in the Commonwealth.

Table 1: A summary of the benchmarked test facilities

Facility	Industry Focus	Technical Capability	TRL (1-9)	Funding Source	Location
NY-BEST TCC & RIT BPC	EV and grid energy storage	Fabrication, testing, commercial certification	4-8 (estimated)	Consortium, state support, private partners, member fees	New York State/ Rochester, NY
UMich Battery Lab	EV and grid energy storage (Li-ion)	Fabrication and testing of pilot-scale batteries	6-7 (estimated)	University, private partner, user fees	Ann Arbor, MI
UWash Clean Energy Testbeds	Clean energy	Fabrication and characterization	6-8 (estimated)	University, user fees	Seattle, WA
UMD CALCE Battery Group	Li-ion reliability	Battery failure analysis	6-9 (estimated)	University, user fees	Maryland
Penn State BATTERY	EV battery integration	Integration simulation and testing	6-7 (estimated)	Unknown	Pennsylvania

1. Introduction

This report provides a benchmarking study for test facilities working on cell and system scale energy storage technologies applicable for grid-integration. The report was prepared for the special legislative commission as established in Section 134 in Chapter 47 in the Acts of 2017 (the Commission), in coordination with Representative Solomon Goldstein-Rose. The research and report was completed by the UMass Clean Energy Extension. The team identified U.S. located test facilities, researched key attributes concerning the technical capabilities and financial establishment and operations of the facilities, and identify questions for further investigation. Research was conducted through internet resources and, as available, direct communications with staff at the test facilities.

1.1 Motivation

The goal of this benchmarking study is to provide a foundation for the Commission to better understand the range of existing test facilities, who they serve, and how the operate, and to help the Commission consider the form and role of a test facility in Massachusetts. To the extent the Commission solicits a consultant to explore the design and business plan and viability for a Massachusetts test facility, this benchmarking report is meant to be helpful in preparing a scope of work and to provide a starting point for a consultant's review of existing facilities.

1.2 Scope

In this report, we aim to benchmark facilities that may offer either competition, or collaboration opportunities, to a possible Massachusetts test facility supporting energy storage development.

Specifically, we concentrated on facilities that:

- Focus on energy storage technologies with primary applications for grid-integrated, inclusive of testing facilities at both cell-level and system-level. Technologies were not limited to lithium ion batteries.
- Are open to private and academic entrepreneurs, startups interested in additional R&D, and/or government research. Test facilities within storage companies that only work on internal R&D were not considered in the benchmarking scope.
- Operate between basic research and finished product. A technology readiness level (TRL) scale is used to consider this aspect of the scope.

Within this scope, we identified 13 facilities, of which 5 were affiliated with universities, 6 were within U.S. DOE National Laboratories, and 2 operated in another manner. We specifically researched whether any facilities pro-actively sought out emerging research to offer testing services or collaboration, and found no such facility.

1.3 Technology Readiness Level (TRL)

For the purposes of this benchmarking, we assessed all facilities in terms of a Technology Readiness Level (TRL) scale. We use the scale adopted by the Massachusetts Clean Energy Center (MassCEC), which is shown the Table 2.

especially with regards to its exact language. At times, we found a facility's position relative to the "Valley of Death" a more useful framing device.

1.4 Disclaimer

This report is a preliminary effort conducted under a condensed timeframe with limited resources. Our aim is to outline the existing energy storage test facilities, provide useful technical and contact information, and offer some remaining questions and key observations. The report recognizes that there may be some additional test facilities that we did not uncover, and that all information reported is not fully verified and only as accurate as our time and resources allowed.

1.5 Research Team and Acknowledgements

This research and report results primarily from the work of Ajey Panday and Reno Sarge who served as engineering interns to the Clean Energy Extension. The project was overseen by Chris Beebe, CEE Research Engineer, and by Dwayne Breger, CEE Director. The team thanks Representative Solomon Goldstein-Rose for his motivation and input.

1.6 Key Terms and Acronyms

DOD: United States Department of Defense.

DOE: United States Department of Energy. Provide funding to National Labs that work at various levels on clean energy.

EV: Electric vehicle.

IP: Intellectual property, including patents and trademarks.

Li-ion battery: lithium-ion battery. Currently leading standard technology for rechargeable batteries in electric cars and consumer electronics.

TRL: Technology Readiness Level. Also referred to as Technology Readiness Coefficient (TRC). An informal measure of how close to deployment a technology is, from theoretical understanding to product proven in the field.

"Valley of Death": Phase of development between proofs-of-concept for basic research and production-ready technology. Relatively few technologies make this gap, which requires a significant level of design, testing, and risk.

2.1 NY-BEST Test and Commercialization Center & RIT Battery Prototyping Center

Industry Focus	Technical Capability	TRL	Funding Source	Location
EV and grid energy storage	Fabrication, testing, commercial certification	4-8 (estimated)	Consortium, state support, private partners, member fees	New York State/ Rochester, NY

The NY-BEST Technology Commercialization Center (TCC) is an energy storage testing facility opened in 2014 in collaboration between the New York Battery and Energy Storage Technology (NY-BEST) Consortium, and testing and certification corporation DNV-GL. The Rochester Institute of Technology (RIT) Battery Prototyping Center (BPC) is an associated fabrication center open to members of NY-BEST. The consortium itself comprises a long list of private companies, universities, and public nonprofits.

Technical Capacity

The facility is now a primary testing site for DNV-GL and is open to members of NY-BEST. A list of the equipment for the RIT Battery Prototyping Center including a full set of equipment for fabricating and characterizing pilot-scale Li-ion cells, as well as a 1000 ft^2 dry room. Equipment for the BPC is given in Appendix I.

Business and Operation

Pricing for access the TCC of BPC is not given—only the price of general membership, which is $500 per year for startups of less than 25 employees. The consortium has a large board of directors comprising executives from member organizations, as well as a small internal administration staff. It is unclear who manages operation of the TCC, but the contact person for the facility is an employee of DNV-GL.

Key Issues and Questions

It would be quite useful to know the detailed equipment list for the TCC, as well as how these facilities are funded. It unclear how much startups are expected to pay for using the facility. This information is especially pertinent because NY-BEST has quite similar goals to the Massachusetts in terms of fostering innovation in energy storage and is a geographically close facility.

2.3 University of Washington Clean Energy Testbeds

Industry Focus	Technical Capability	TRL	Funding Source	Location
Clean energy	Fabrication and characterization	6-8 (estimated)	University, user fees	Seattle, WA

The University of Washington Clean Energy Testbeds (WCET) was opened in 2017 as a 15,000 ft^2 facility run by the University of Washington Clean Energy Institute (CEI).

Technical Capacity

The WCET is open to entrepreneurs working on all aspects of clean energy – including grid-integrated energy storage. The facility is split into three testbeds: Scale-Up and Characterization, Systems Integration, and Research Training. The Scale-Up and Characterization Testbed has a wide array of fabrication and testing instruments (not limited to energy storage), and the Systems Integration Testbed in particular has a 40kWh/30W energy storage system for testing battery management systems for grid applications. See Appendix I for a list of key equipment in the Clean Energy Testbed (Note: we only noted equipment we were certain were for battery fabrication and testing.)

Budget and Operation

The entire WCET has a staff of eight, consisting of two directors (one technical and one managing), three staff scientists, one business development specialist, one entrepreneur-in-residence, and one investor-in-residence. The staffing implies a focus on commercialization, as opposed to a focus on research and early stage development.

Effectively, a startup could use the WCET for most of their fabrication and testing work, paying for procedures in an "a la carte" manner, with discounts on some procedures given for members, who pay a yearly or monthly fee. Currently, the list of users and programs at the WCET are rather sparse, although this may be a result of the lab being still in its first year.

The University of Washington CEI has a diversity program called Diversity in Clean Energy (DICE), which is a student-led group.

Key Issues and Questions

We were not able to clarify the sources or amounts of initial funding and annual budget for the facility. However, an initial press release noted that the Washington State legislature appropriated $8 million for initial construction of the facility.

The business design of having two directors – one managing and one technical – is noteworthy and further outreach to WCET on this structure may be helpful.

2.5 Penn State BATTERY Lab

Industry Focus	Technical Capability	TRL	Funding Source	Location
EV battery integration	Integration simulation and testing	6-7 (estimated)	Unknown	Pennsylvania

The Penn State Battery Application Technology Testing and Energy Research laboratorY (BATTERY) is a battery integration and testing facility affiliated with the Penn State Larson Transportation Institute. To that end, it focuses primarily on EV applications, using an AeroVironment ABC150 and AV900, a walk-in temperature-controlled test chamber, and hardware-in-loop (HIL) simulations. There is very little information on its website regarding collaboration or pricing, beyond very basic contact information for the director of the lab.

3.1 Sandia National Lab BATLab and ESAL

Industry Focus	Technical Capability	TRL	Funding Source	Location
Abuse Testing	MW-scale electrical testing	4-5 (estimated)	Federal	New Mexico

Sandia's primary battery testing facility, the Battery Abuse Testing Lab (BATLab), focuses less on designing novel battery technology than on stress-testing existing technologies. Sandia also has a very large battery calorimetry lab, a Li-ion prototyping facility, and a test lab and testbed for energy storage, called the Energy Storage Analysis Lab (ESAL).

Technical Capacity

ESAL can test a wide-array of storage technologies, from mA to 1000A scale. They can even characterize MW scale systems, important for utility scale grid-integrated storage. The facility can account for factors like energy time shift, load following, power quality, and other considerations relevant to operators in the grid.

Business and Operation

The BATLab primarily works for the DOE Office of Vehicle Technologies, testing technology for EV applications. However, the lab also conducts research for other offices in the DOE, DOD, NASA, and private contractors. ESAL, meanwhile, works with organizations working on the grid, including independent system operators (ISOs) and regional transmission operators (RTOs), power producers, utilities, and R&D labs in academia and government.

Key Issues and Questions

Further details of these labs' toolsets and their benchmarks for testing should be explored.

3.3 National Renewable Energy Lab (NREL)

Industry Focus	Technical Capability	TRL	Funding Source	Location
Electric vehicles and grid integration	Simulation for design, characterization, and integration	3-5*(Transport)/ 6-7*(ESIF)	Federal	Colorado

The National Renewable Energy Lab (NREL) has two hubs for battery research: one in its Transportation department and one in its Energy Storage Integration Facility. The former is focusing on novel battery chemistry, including improved Li-ion, solid-state, lithium-air, and even liquid batteries. The latter, meanwhile, focuses on MW scale integration to power grids, including operation of buildings, vehicle charging systems, and energy storage.

Technical Capacity

NREL's Transportation department uses two simulation systems: they model fabrication with the Computer-Aided Engineering for Electric Drive Vehicle Batteries (CAEBAT) tool, and they model operation with the Battery Lifetime Analysis and Simulation Tool (BLAST). CAEBAT is effectively a CAD suite for battery technology, whereas BLAST considers temperature, state-of-charge history, current levels, and cycle depth and frequency to forecast the longevity and performance of battery systems in complex environments.

The ESIF, meanwhile is developing a hardware-in-the-loop (HIL) test platform for ~10 kW grid-connected energy storage systems – roughly the scale of Tesla Powerwall units. The platform can model how these energy storage systems behave within the grid, both with and without solar integration.

We found no information regarding hardware measures for fabricating and testing batteries.

Business and Operation

NREL is a DOE-supported lab, but it also frequently partners with large corporations, government programs, utilities, and other labs. They do sponsor incubators such as the Wells Fargo IN^2 incubator, which focuses on clean energy.

Key Issues and Questions

We were not able to establish what sort of hardware NREL uses regarding battery fabrication and testing, and how much of their CAEBAT and BLAST toolset is applicable to grid applications.

3.5 Idaho National Lab Battery Test Center

Industry Focus	Technical Capability	TRL	Funding Source	Location
EV batteries	Testing of pilot and commercial-scale batteries	<4; 7-8 (given)	$6-8 million/year	Idaho

The Battery Test Center at Idaho National Laboratory (INL) is the primary center for battery technology testing for the DOE Office of Energy Efficiency and Renewable Energy (EERE). The test facility provides 17,500 ft^2 of laboratory space equipped with tools that allow testing of several hundred batteries at the same time, ranging from small cells to complete EV-scale battery packs.

Technical Capacity

The INL Battery Test Center offers a wide set of testing equipment holding over 800 channels, with some units supplying DC voltages up to 1000 V and power as high as 350 kW. Some of these units can be operated independently of each other, and tests can be conducted in walk-in chambers that can be set to between -65°C and 190°C. The facility can also test battery vibration and operate with CAN buses, allowing for better simulation of EV battery systems.

Business and Operation

INL is primarily DOE-funded: only 2% of its work is from private contracts. However, the Battery Test Center sources 10-15% of its work from private contracts, which are often with small companies (although these contracts only rarely involve SBIR grants).

The Battery Test Center has an annual budget between $6-8 million, 15 permanent staff, and a small cycling cohort of interns and postdoc researchers. The facility is led by principal investigators (PIs), with test engineers who report to the PIs.

Key Issues and Questions

The group lead did not offer a detailed list of equipment.

4. Additional Test Facilities

Most labs we found either are affiliated with universities or are large DOE-supported endeavors. There are a few exceptions, however, including a new facility opened by the Fraunhofer Center for Sustainable Energy Systems in Boston.

4.2 Fraunhofer Center for Sustainability Energy Systems (CSE) Energy Storage Integration Lab

Industry Focus	Technical Capability	TRL	Funding Source	Location
Clean energy system integration	Lab and field testing of large systems	>6 (given)	Private contracting	South Boston, MA

The Fraunhofer Center for Sustainability Energy Systems (CSE) Energy Storage Integration (ESI) Lab is a very new testing facility (opened December 2017) located in South Boston and run by research nonprofit Fraunhofer. It focuses on testing systems for integration within clean energy systems, especially on designing standards for safety and security within house-scale clean energy systems.

Technical Capacity

The ESI Lab tests late-stage prototypes for clean energy storage systems using a model "smart-home," and a combination of simulated and hardware components. This model accounts for rooftop solar arrays, load banks, and energy storage systems. The lab also conducts field tests for larger systems. All tests are performed by Fraunhofer staff.

At the systems level that the ESI Lab operates, Li-ion and liquid-flow batteries are both testing under similar equipment and integration – they are simply energy storage systems. The primary difference is that liquid-flow batteries tend to be built and tested at larger scales, necessitating field testing more often than lab testing.

Despite their work in testing energy systems, the ESI lab does not award certifications in the manner of UL or DNV.

Business and Operation

Fraunhofer CSE pulls from a wide array of funding, including MassCEC support and private R&D contracts. The most common structure for private R&D contracts is that the client approaches Fraunhofer with a prototype and a series of questions about the operation of their own system. From there, Fraunhofer and the client collaborate to determine what needs to be tested and how one should test those parameters. Once the tests are established, Fraunhofer runs the tests themselves.

A key issue in the energy storage industry is that there is no agreed upon standard for safety, efficiency, and security within grid-integrated energy storage systems. Thus, part of the ESI Lab's work is to help establish those standards.

At this point, the Fraunhofer ESI Lab is trying to promote itself, which is perhaps the closest any of the benchmarked labs approach to actively seeking out promising research to test.

Key Issues and Questions

The individuals at Fraunhofer CSE did not give exact specifications regarding the equipment in their lab, and they were unclear as to which elements were hardware emulations and which were simulated. It may be interesting to explore how early in the TRL scale one can operate before the testing requirements for liquid-flow and Li-ion batteries diverge significantly.

As provided in Figure 2 and discussed above, the identified test facilities tend to cluster in the low TRL range in the national labs and in the higher TRL range for the university facilities. NY BEST, NREL, and Sandia do extend into the mid TRL scale. The extent to which these available test facilities sufficiently address the technology development needs and can adequately serve and encourage a Massachusetts energy storage cluster, or whether gaps in scope or geographical convenience create opportunities for a test facility in Massachusetts, will require further investigation. Coordinating a test facility with research institutions, clean energy incubators, and advanced manufacturing in Massachusetts should be further explored.

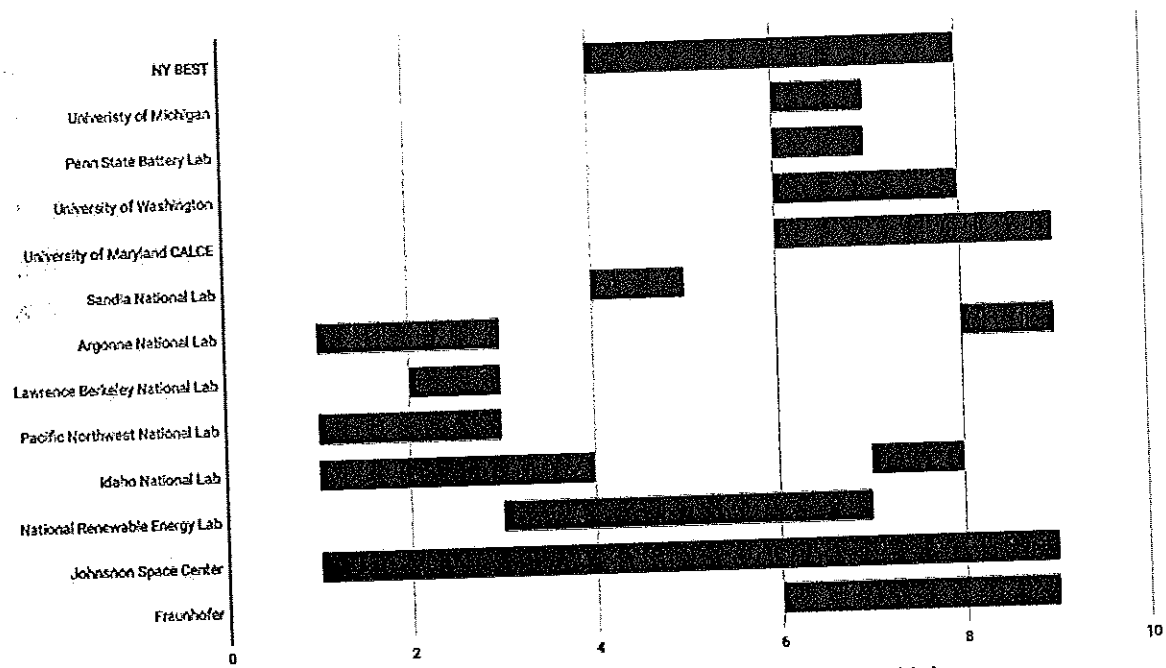

Figure 2: TRL ranges of identified and benchmarked labs

RIT Battery Prototyping Center (NY-BEST)

	Coin-cell Scale	Cylinder/Pouch-cell Scale
Mixing	Flaktek Speedmixer 150.1 FV. Buhler Homogenizing Disper DH-2.5[1]	Bhuler Hivis HM-2P-01. Buhler Laboratory Disk Mill
	Primix FILMIX 56-L	
	Malvern Kinexus Rheometer	
Coating	MTI blade coating system	TBD
Calendaring	TOB: 150C[2]	Independent Machine Company Calendar system: 150C
Electrode Prep	Coin-cell punches Steel rule die custom punches and press	Slitting machine by Independent Machine Company or Delta Mod. Sovema SoLith RPN300
Cell Assembly	Pred Materials coin cell crimper and coin cell disassembly tool	Sovema SoLith CWM150 (for 18650 cells). Sovema SoLith Automatic Cell Winder (for prismatic cells)
Testing	Add 64 channels to pilot-scale system	Bitrode system (32-channel,1A,0-5V). Arbin System (32-channel,5A,0-5V). Both in Thermal channel
Characterization	Hitachi S900 (scanning electron) Brookfield Viscometer[3] Amatek VersaSTAT 4 (Impedence analysis) Bruker D2 PHASER (tabletop X-ray diffractometer) Vacuum Atmospheres Glovebox HORIBA Raman (spctrometer) TA Instruments DSC series (Differential Scanning Calorimeter) TA Instruments TGA series (thermogravimetric analyzer) TA instruments DMA series (Dynamic Mechanical Analyzer) Netzch MMC 274 Nexus + High Temperature Coin Cell Module	

[1] We could not find this particular Buhler unit online.
[2] We could not find the company TOB online.
[3] Brookfield offers a wide array of viscometers.

UMD CALCE Battery Group

Electrical Characterization	Cadex C8000 Battery Test system Agilent 34970A Data Acquistion INL Battery Testing System Neware BTS4000 Arbin BT2000 Battery Test System Arbin BT-1
Environmental Chambers	MBRAUN Glove Box Workstation Yamato DVS 402 Thermo Temperature Humidity Chamber
Mechanical Testing	TA's Dynamic Mechanical Analyzer Data Physics 1D Electrodynamic Shaker Perkin-Elmer Differential Scanning Calorimeter Vibrotron 6D-Electrodynamic Shaker DAC Torsion Tester Mechanical Test System
Failure Analysis	Zeiss AxioCam MRc5 Optical Microscopy Agilent Foruier Transform Infrared Spectroscopy Nikon Atomic Force Microscopy Fischer X-ray Fluorescence Microscopy

[illegible]	Malvern zetasizer Nano ZS – Dynamic Light Scattering (DLS) Analyzer Angstrom Engineering NexDep Thermal Evaporator Golvebox-Integrated Sawatec: SM-150 SpinCoater Laurell Spin Coater Glove Box with Solar Simulator and EQE Oriel Verasol-2 Solar Simulator QEPVSI-b Measurement system Hohsen HSACC-10 Automatic Coin Cell Crimper Mbraun Argon Battery Glovebox Maccor 4000 64 channel multifunctional battery testing system Maccor MTC-020 battery-test temperature chambers

Q1 Name:

Answered: 79 Skipped: 2

#	RESPONSES	DATE
1	Tom Ollila	1/5/2018 3:02 PM
2	Tom McCarran	1/5/2018 12:22 PM
3	Erik Limpaecher	1/4/2018 3:19 PM
4	Jonathan Milley	1/3/2018 3:47 PM
5	Charles Van Winkle	1/3/2018 2:46 PM
6	Mark Worthingotn	1/3/2018 11:15 AM
7	Jeffrey Rhodin	1/3/2018 9:48 AM
8	Kurt Roth	1/3/2018 9:30 AM
9	Phil Fischer	1/3/2018 1:47 AM
10	Ryan Spray	1/2/2018 5:57 PM
11	Carlos Gonzalez	1/2/2018 5:33 PM
12	Ben Lavoie	1/2/2018 4:25 PM
13	Chris Cantone	1/2/2018 3:19 PM
14	Gabriel Loos	1/2/2018 2:51 PM
15	Haresh Kamath	1/2/2018 2:35 PM
16	Matthew Kromer	1/2/2018 1:51 PM
17	David Manke	1/2/2018 1:23 PM
18	Angie Grant	1/2/2018 12:30 PM
19	Joe McLean	1/2/2018 12:05 PM
20	Dan Cook	1/2/2018 11:52 AM
21	Kristin Brief	1/2/2018 11:26 AM
22	Margaret Campbell	1/2/2018 11:26 AM
23	Clayton Burns	1/2/2018 11:26 AM
24	ZAFFAR KHAN	1/2/2018 11:08 AM
25	Robert J Davidson	1/2/2018 10:55 AM
26	Dr. Babu Chalamala	1/2/2018 10:55 AM
27	Haskell Werlin	1/2/2018 10:47 AM
28	David Chamberlain	1/2/2018 10:32 AM
29	steve weiss	1/2/2018 10:25 AM
30	Matthew Mayerhofer	1/2/2018 10:22 AM
31	Ravindra Datta	1/2/2018 10:20 AM
32	Joshua Rogol	1/2/2018 10:14 AM
33	James Redden	1/2/2018 10:05 AM
34	Sean Hamilton	1/2/2018 10:03 AM
35	DEAN BERLIN	1/2/2018 10:00 AM

77	William A. Franks	12/19/2017 3:54 PM
78	Daniel Abrahamson	12/19/2017 3:53 PM
79	Drew Pierson	12/19/2017 3:52 PM

36	MassDevelopment	1/2/2018 9:57 AM
37	DRF Engineering Services LLC	1/2/2018 9:55 AM
38	City of Boston	1/2/2018 9:53 AM
39	RetroCool Energy Services, Inc.	1/2/2018 9:52 AM
40	E4TheFuture	1/2/2018 9:52 AM
41	Manager	1/2/2018 9:50 AM
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44	XRG LLC	12/28/2017 1:08 PM
45	Renewable Energy International LLC	12/23/2017 5:46 PM
46	Feblowitz Energy Consulting	12/21/2017 4:06 PM
47	Harvard Student	12/20/2017 5:34 PM
48	WattJoule	12/20/2017 1:44 PM
49	Convergent Energy and Power	12/20/2017 12:49 PM
50	Duke Energy	12/20/2017 9:49 AM
51	Safe Hydrogen, LLC	12/20/2017 9:00 AM
52	Massachusetts Hydrogen Coalition	12/20/2017 8:34 AM
53	MMWEC	12/20/2017 8:11 AM
54	Eversource	12/20/2017 7:41 AM
55	West Boylston Municipal Lighting Plant	12/20/2017 7:12 AM
56	Sterling Municipal Light Department	12/20/2017 6:46 AM
57	Levisys	12/19/2017 11:03 PM
58	MIT	12/19/2017 10:47 PM
59	Hyde Engineering Services, Inc.	12/19/2017 8:33 PM
60	Cadence Development	12/19/2017 8:33 PM
61	UMass Amherst	12/19/2017 6:43 PM
62	Sparkplug Power	12/19/2017 6:39 PM
63	Cape & Vineyard Electric Cooperative	12/19/2017 5:00 PM
64	Boston Fire Dept	12/19/2017 4:57 PM
65	Swift Current Energy	12/19/2017 4:39 PM
66	Mosaic Power	12/19/2017 4:39 PM
67	MA DPU	12/19/2017 4:33 PM
68	Worcester Polytechnic Institute	12/19/2017 4:32 PM
69	Holden Municipal Light Dept	12/19/2017 4:09 PM
70	Vionx Energy	12/19/2017 4:04 PM
71	Marblehead Municipal Light Department	12/19/2017 4:03 PM
72	Development	12/19/2017 4:01 PM
73	NFPA	12/19/2017 4:01 PM
74	Town of Middleborough	12/19/2017 3:58 PM
75	Mosaic Power	12/19/2017 3:57 PM
76	Independent Power and Renewable Energy LLC	12/19/2017 3:54 PM

Q3 Where is your company located (city/town)?

Answered: 79 Skipped: 2

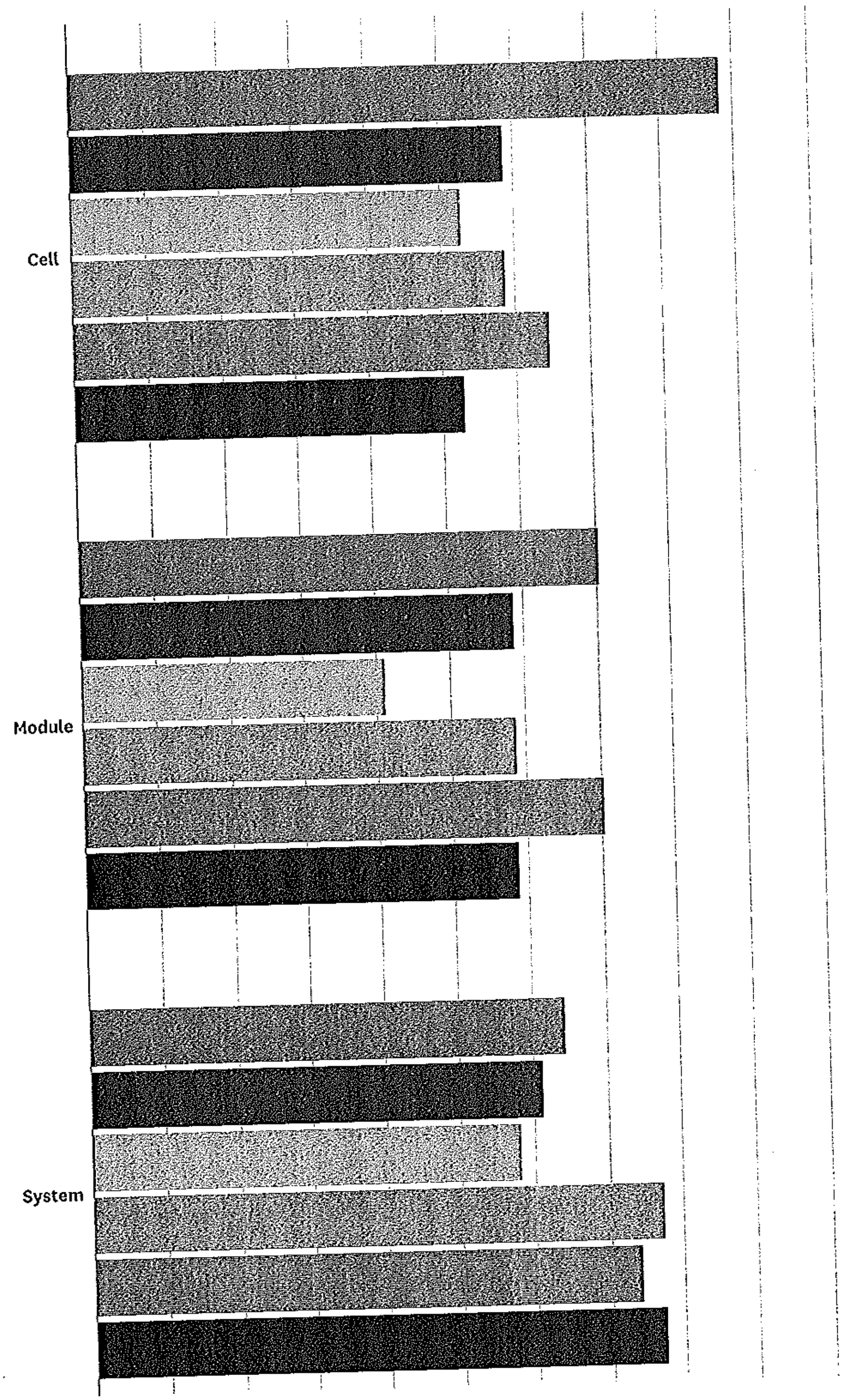
#	RESPONSES	DATE
1	Reading	1/5/2018 3:02 PM
2	Edgartown	1/5/2018 12:22 PM
3	Lexington	1/4/2018 3:19 PM
4	Woburn, MA	1/3/2018 3:47 PM
5	Waterbury, VT	1/3/2018 2:46 PM
6	Lancaster, MA	1/3/2018 11:15 AM
7	Waltham, MA	1/3/2018 9:48 AM
8	Boston	1/3/2018 9:30 AM
9	Westborough	1/3/2018 1:47 AM
10	Natick, MA	1/2/2018 5:57 PM
11	Brooklyn, New York	1/2/2018 5:33 PM
12	Framingham, MA	1/2/2018 4:25 PM
13	Boston, MA	1/2/2018 3:19 PM
14	Radnor, PA	1/2/2018 2:51 PM
15	Palo Alto, California	1/2/2018 2:35 PM
16	Boston, MA	1/2/2018 1:51 PM
17	North Dartmouth, MA	1/2/2018 1:23 PM
18	Edgartown	1/2/2018 12:30 PM
19	California / Boston, Mass	1/2/2018 12:05 PM
20	Carlisle, MA	1/2/2018 11:52 AM
21	Marlborough, MA	1/2/2018 11:26 AM
22	Bolton	1/2/2018 11:26 AM
23	Waltham	1/2/2018 11:26 AM
24	TRINIDAD WEST INDIES	1/2/2018 11:08 AM
25	Easley, SC	1/2/2018 10:55 AM
26	Albuquerque, NM	1/2/2018 10:55 AM
27	Harvard	1/2/2018 10:47 AM
28	Waltham, MA	1/2/2018 10:32 AM
29	fall river, ma	1/2/2018 10:25 AM
30	Needham, MA	1/2/2018 10:22 AM
31	Worcester	1/2/2018 10:20 AM
32	Kalispell, Montana	1/2/2018 10:14 AM
33	Framingham	1/2/2018 10:05 AM
34	Sterling Ma	1/2/2018 10:03 AM
35	WALTHAM, MA	1/2/2018 10:00 AM

77	Wells, ME	12/19/2017 3:54 PM
78	Boston	12/19/2017 3:53 PM
79	Boston	12/19/2017 3:52 PM

3	Energy Conservation Consultant	1/3/2018 9:48 AM
4	Applied R&D organization	1/3/2018 9:30 AM
5	Science / Engineering Consulting	1/2/2018 5:57 PM
6	Project Developer and EPC/Installer	1/2/2018 4:25 PM
7	Renewable Energy Development Company	1/2/2018 2:51 PM
8	Non-profit collaborative research organization performing public interest research	1/2/2018 2:35 PM
9	Research & Development	1/2/2018 1:51 PM
10	End user	1/2/2018 12:30 PM
11	Representative for Storage Technology Company	1/2/2018 11:52 AM
12	established renewable energy and storage system developer and consultant	1/2/2018 11:26 AM
13	Code Consultant specializing in Energy Storage	1/2/2018 10:55 AM
14	National Laboratory	1/2/2018 10:55 AM
15	solar and storgage engineering firm	1/2/2018 10:47 AM
16	End User	1/2/2018 10:32 AM
17	End User	1/2/2018 10:22 AM
18	Municipal Utility with 1 utility scale battery storage project and currently building another community solar and storage project	1/2/2018 10:03 AM
19	Energy storage consultant	1/2/2018 9:55 AM
20	Municipal Government	1/2/2018 9:53 AM
21	Non-profit funding and organizing innovative clean energy strategies	1/2/2018 9:52 AM
22	Policy Maker / Program Coordinator	1/2/2018 9:50 AM
23	Storage Consultant	12/28/2017 4:28 PM
24	Energy Services Evaluator	12/28/2017 4:08 PM
25	Utility Scale Solar Developer	12/23/2017 5:46 PM
26	Consultant and advisor	12/21/2017 4:06 PM
27	Storage System Developer	12/20/2017 12:49 PM
28	Utility Based Storage Provider	12/20/2017 9:49 AM
29	Industry support	12/20/2017 8:34 AM
30	Municipal Wholesale Power Generator	12/20/2017 8:11 AM
31	Energy Consultant	12/19/2017 8:33 PM
32	Energy Cooperative	12/19/2017 5:00 PM
33	Public safety	12/19/2017 4:57 PM
34	Annonymous	12/19/2017 4:01 PM
35	Standards Development	12/19/2017 4:01 PM
36	Municipality	12/19/2017 3:58 PM
37	Local representative of Stornetic GmbH (www.stornetic.com).	12/19/2017 3:54 PM
38	Utility/Public Service and Transportation	12/19/2017 3:53 PM
39	Solar developer	12/19/2017 3:52 PM

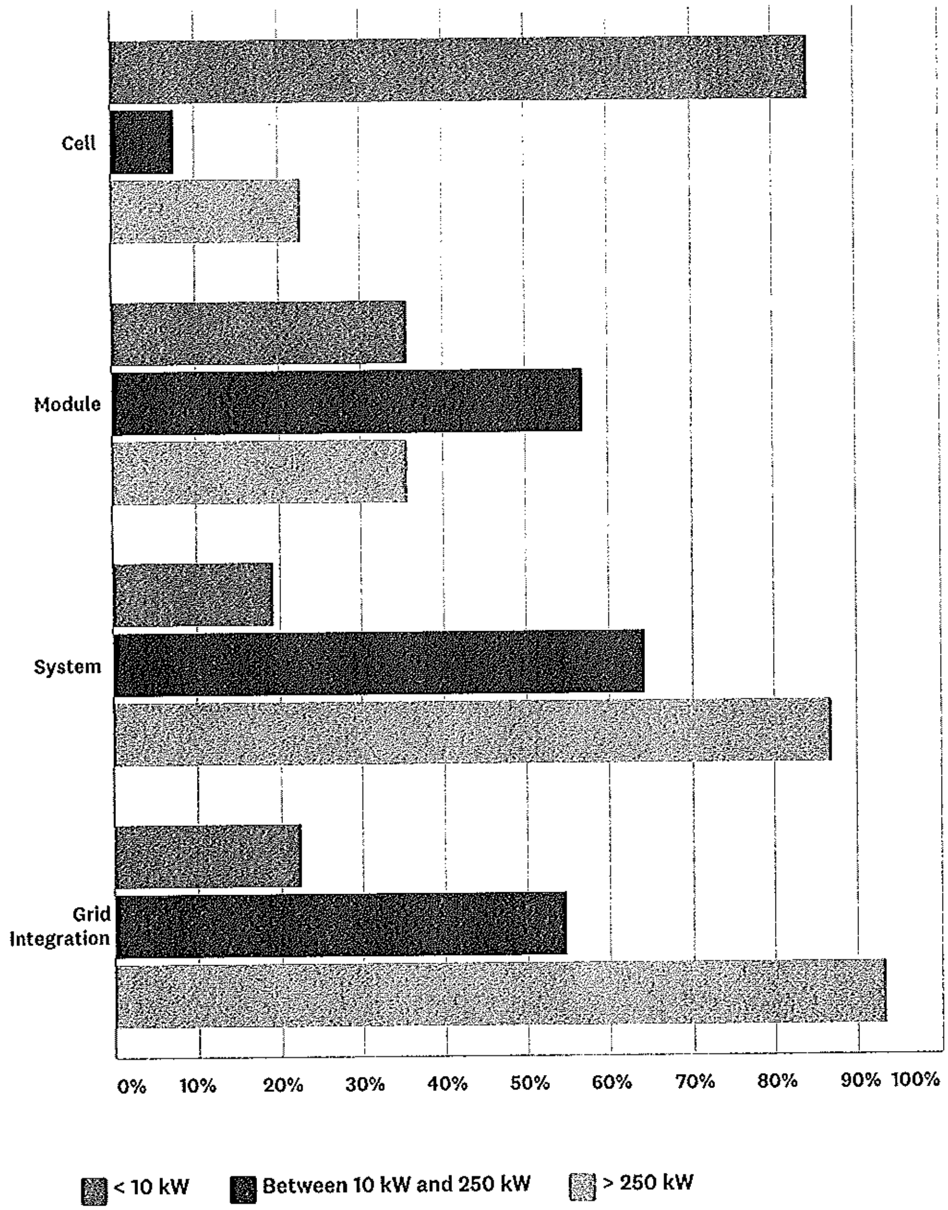
Q6 What type of battery storage testing needs do you have or anticipate having in the next 1-5 years? Please respond for each modular level and select all that apply.

Answered: 36 Skipped: 45



Q7 At what scales do you require battery storage testing capabilities? (Select all that apply)

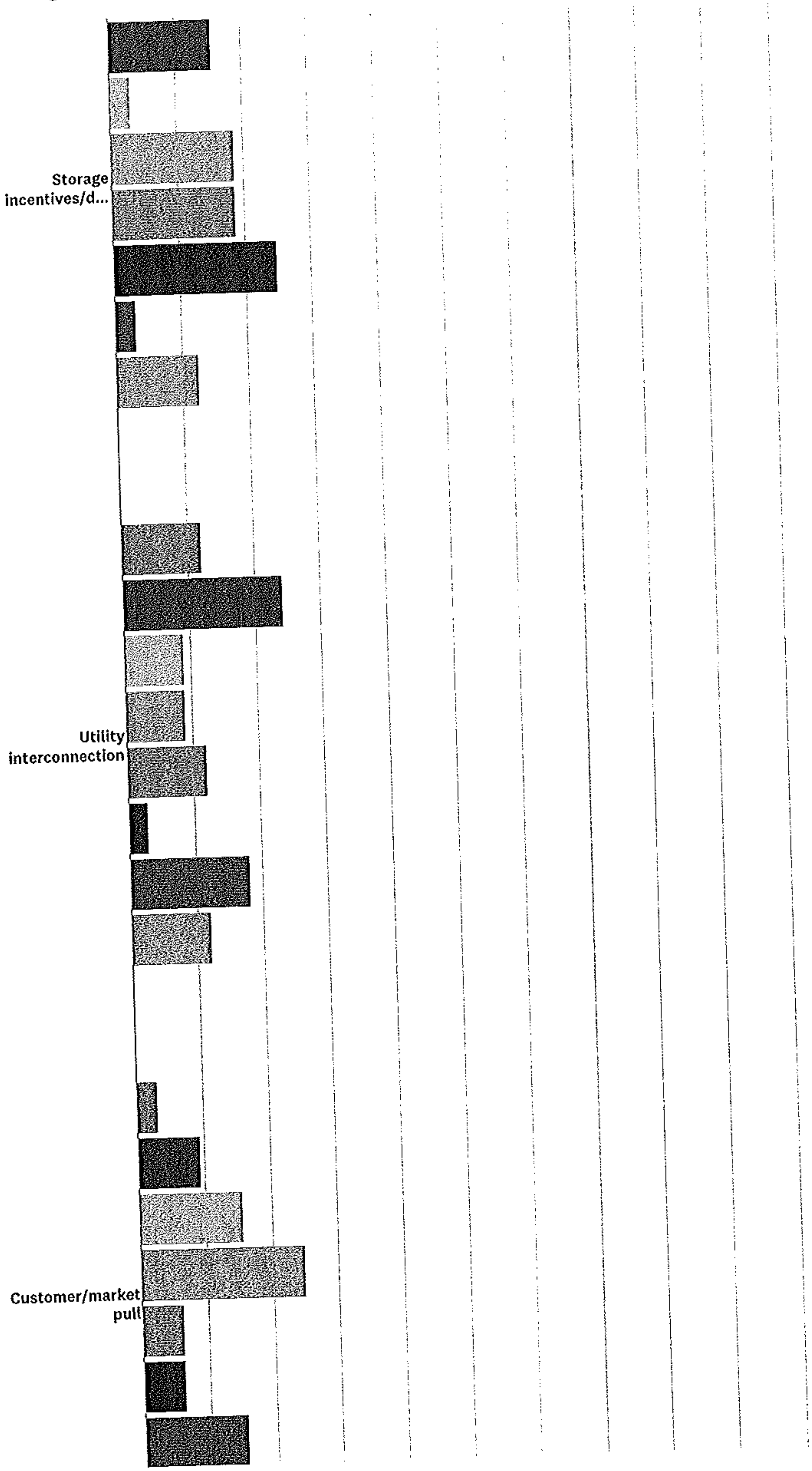
Answered: 35 Skipped: 46

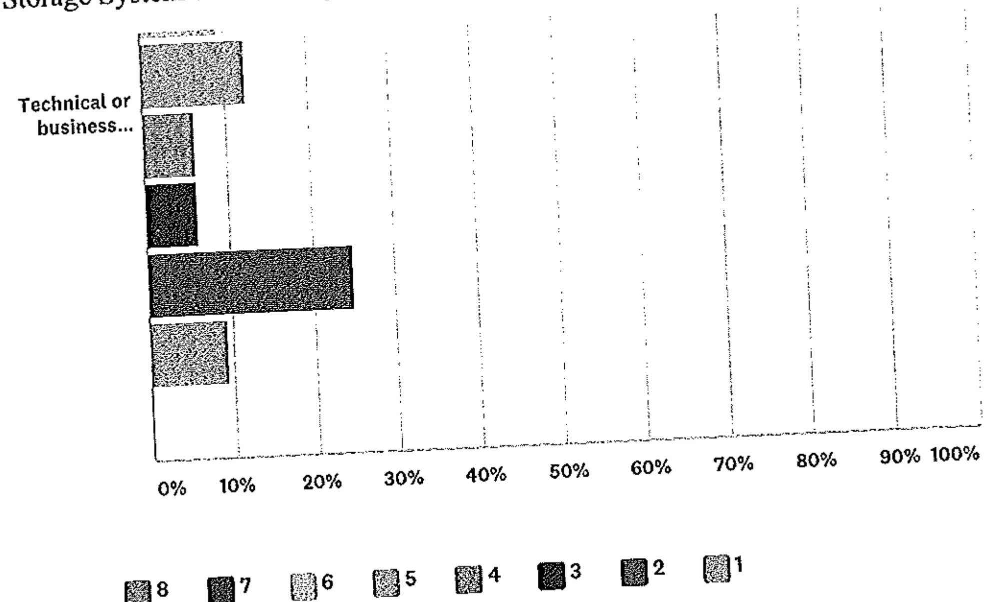


	< 10 KW	BETWEEN 10 KW AND 250 KW	> 250 KW	TOTAL RESPONDENTS
Cell	84.62% 11	7.69% 1	23.08% 3	13
Module	35.71% 5	57.14% 8	35.71% 5	14
System	19.35% 6	64.52% 20	87.10% 27	31
Grid Integration	22.58% 7	54.84% 17	93.55% 29	31

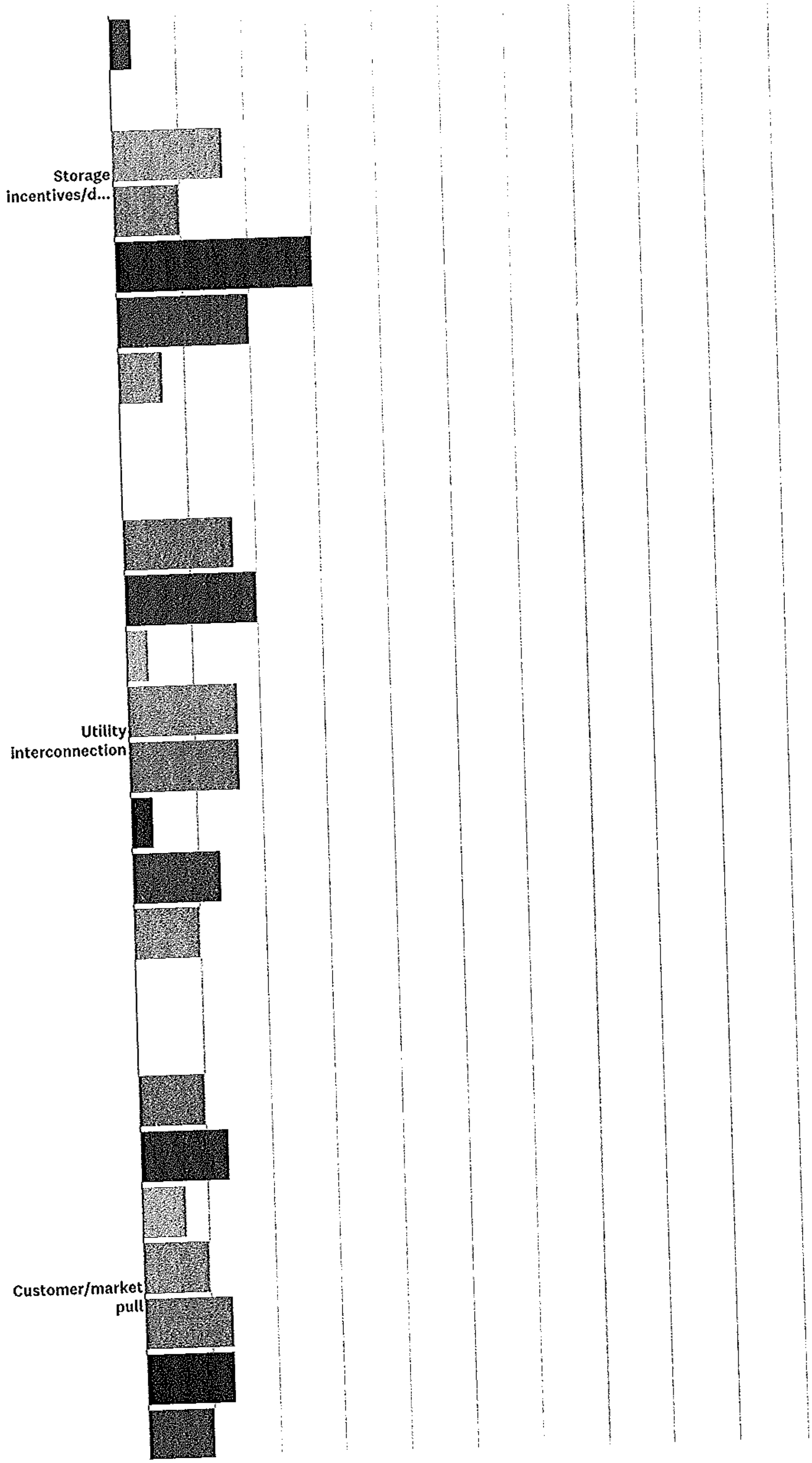
10	demonstrate safety to AHJs as NYSERDA is doing	12/19/2017 6:46 PM
11	n/a	12/19/2017 4:12 PM
12	We make our own cells	12/19/2017 4:10 PM
13	Fire testing to develop safety regulations	12/19/2017 4:09 PM

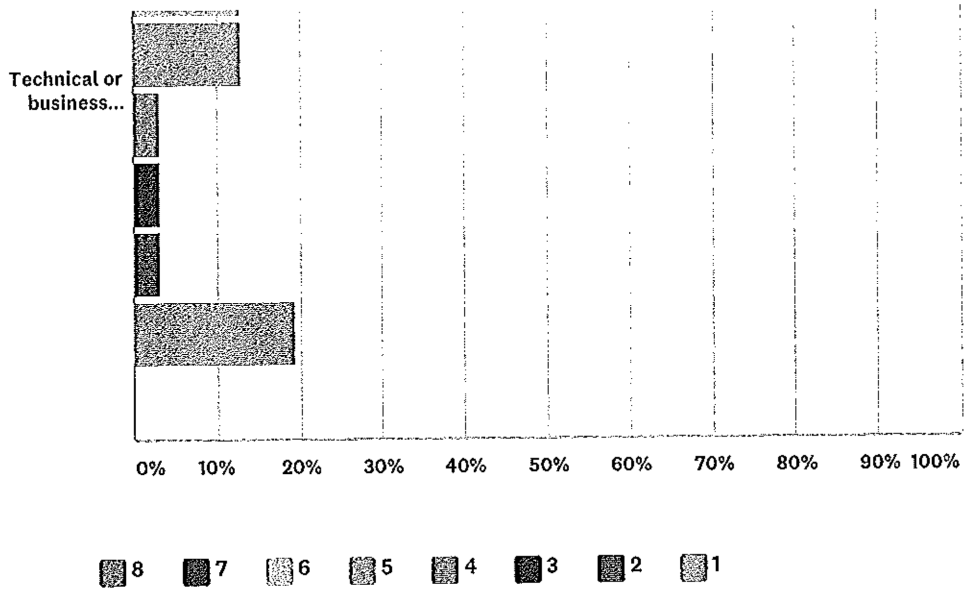
7	We don't test but won't enter the market aggressively until the definitive performance of different battery types is known.	12/19/2017 3:56 PM


Storage incentives/d...
Utility interconnection
Customer/market pull

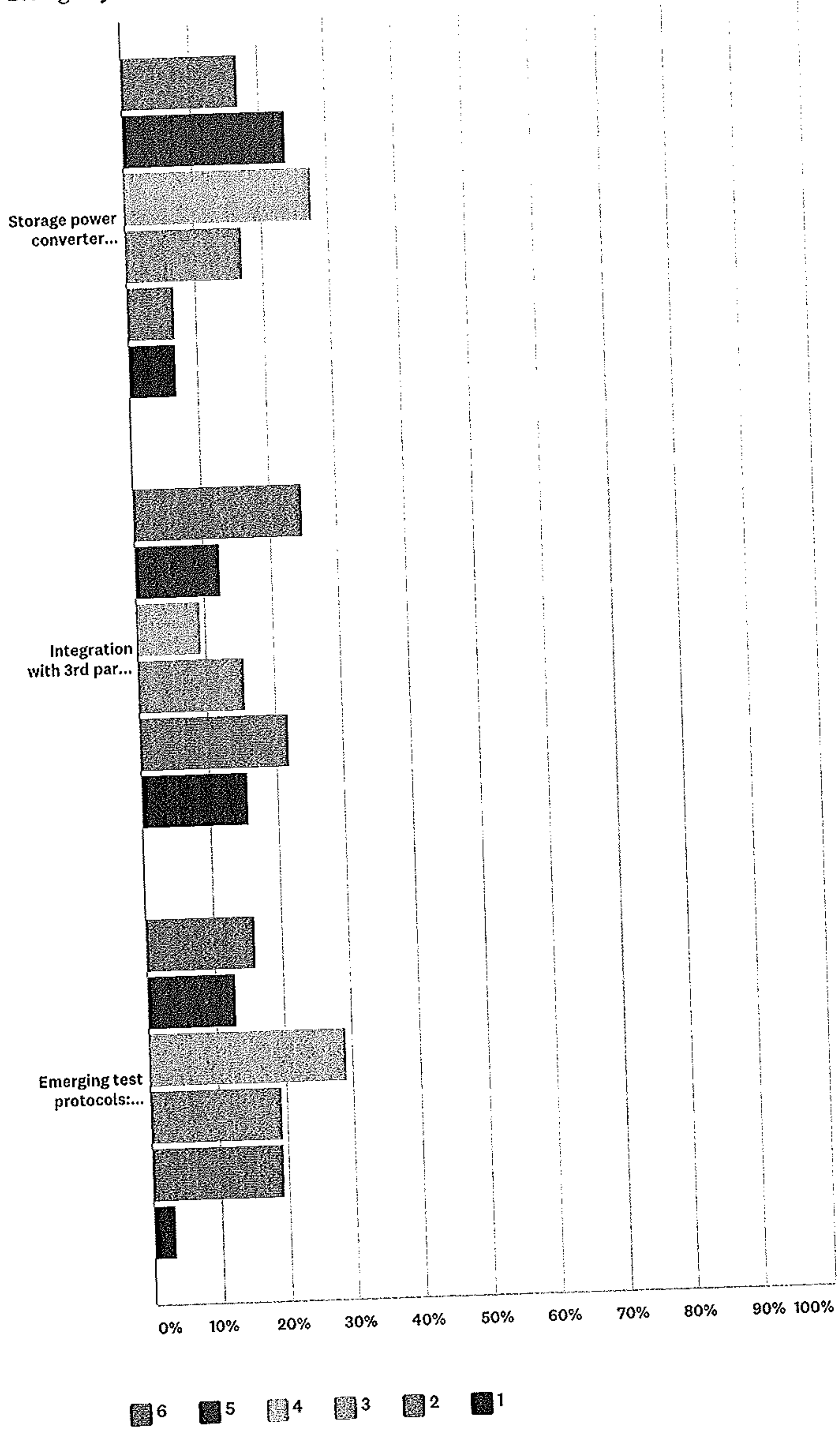


	8	7	6	5	4	3	2	1	TOTAL
Access to affordable test facilities	29.03% 9	6.45% 2	9.68% 3	16.13% 5	12.90% 4	12.90% 4	6.45% 2	6.45% 2	31
Storage policy	6.67% 2	3.33% 1	23.33% 7	6.67% 2	6.67% 2	23.33% 7	20.00% 6	10.00% 3	30
Storage incentives/development grants	3.13% 1	15.63% 5	3.13% 1	18.75% 6	18.75% 6	25.00% 8	3.13% 1	12.50% 4	32
Utility interconnection	12.12% 4	24.24% 8	9.09% 3	9.09% 3	12.12% 4	3.03% 1	18.18% 6	12.12% 4	33
Customer/market pull	3.13% 1	9.38% 3	15.63% 5	25.00% 8	6.25% 2	6.25% 2	15.63% 5	18.75% 6	32
Project Finance	3.23% 1	16.13% 5	25.81% 8	6.45% 2	25.81% 8	6.45% 2	6.45% 2	9.68% 3	31
Access to corporate capital	24.24% 8	12.12% 4	6.06% 2	6.06% 2	12.12% 4	18.18% 6	6.06% 2	15.15% 5	33
Technical or business experience	18.75% 6	12.50% 4	9.38% 3	12.50% 4	6.25% 2	6.25% 2	25.00% 8	9.38% 3	32


Storage incentives/d...
Utility interconnection
Customer/market pull



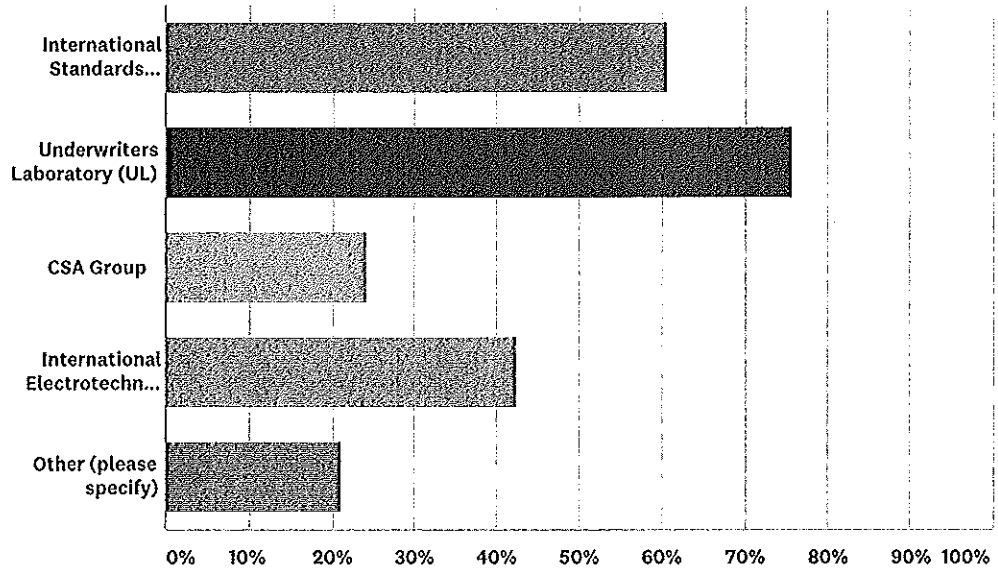
	8	7	6	5	4	3	2	1	TOTAL
Access to affordable test facilities	19.35% 6	9.68% 3	32.26% 10	9.68% 3	12.90% 4	9.68% 3	3.23% 1	3.23% 1	31
Storage policy	6.67% 2	6.67% 2	10.00% 3	10.00% 3	10.00% 3	10.00% 3	33.33% 10	13.33% 4	30
Storage incentives/development grants	13.33% 4	3.33% 1	0.00% 0	16.67% 5	10.00% 3	30.00% 9	20.00% 6	6.67% 2	30
Utility interconnection	16.67% 5	20.00% 6	3.33% 1	16.67% 5	16.67% 5	3.33% 1	13.33% 4	10.00% 3	30
Customer/market pull	10.00% 3	13.33% 4	6.67% 2	10.00% 3	13.33% 4	13.33% 4	10.00% 3	23.33% 7	30
Project Finance	3.33% 1	10.00% 3	13.33% 4	13.33% 4	20.00% 6	20.00% 6	10.00% 3	10.00% 3	30
Access to corporate capital	12.90% 4	6.45% 2	22.58% 7	9.68% 3	16.13% 5	12.90% 4	9.68% 3	9.68% 3	31
Technical or business experience	19.35% 6	25.81% 8	12.90% 4	12.90% 4	3.23% 1	3.23% 1	3.23% 1	19.35% 6	31



	6	5	4	3	2	1	TOTAL

Q13 What lab accreditations would you expect such a lab to have? (Select all that apply)

Answered: 33 Skipped: 48



ANSWER CHOICES	RESPONSES	
International Standards Organization (ISO)	60.61%	20
Underwriters Laboratory (UL)	75.76%	25
CSA Group	24.24%	8
International Electrotechnical Commission (IEC)	42.42%	14
Other (please specify)	21.21%	7
Total Respondents: 33		

#	OTHER (PLEASE SPECIFY)	DATE
1	Thermal Energy Storage System Performance Verification	1/2/2018 11:57 AM
2	IEEE	1/2/2018 11:40 AM
3	Laboratories accredited (for the specific test method under consideration) by an accreditation body that is a signatory to the Mutual Recognition Arrangement (MRA) of the International Laboratory Accreditation Cooperation (ILAC) such as the International Accreditation Service	1/2/2018 11:07 AM
4	not applicable question at this stage	1/2/2018 10:01 AM
5	MESA/SunSpec Alliance	12/28/2017 4:44 PM
6	National Electric & Fire Safety Codes	12/20/2017 1:55 PM
7	Privately run facilities only	12/20/2017 7:18 AM

Q15 If you are currently using an existing battery storage test facility, what are your barriers to using this facility (list up to 3 barriers)?

Answered: 11 Skipped: 70

ANSWER CHOICES	RESPONSES	
1.	100.00%	11
2.	45.45%	5
3.	27.27%	3

#	1.	DATE
1	Facilities are all underutilized and are desperately casting around for business	1/2/2018 2:46 PM
2	Scheduling ..	1/2/2018 11:12 AM
3	none	1/2/2018 10:45 AM
4	Funding	1/2/2018 10:27 AM
5	Inconvenience of National Lab	12/28/2017 4:50 PM
6	NA	12/20/2017 2:00 PM
7	Price	12/20/2017 9:59 AM
8	None	12/20/2017 6:57 AM
9	Building grid connection	12/19/2017 6:53 PM
10	hard to access	12/19/2017 4:41 PM
11	Impossible to transport full system	12/19/2017 4:13 PM

#	2.	DATE
1	Lab time costs	12/28/2017 4:50 PM
2	Capabilities	12/20/2017 9:59 AM
3	Level of instrumentation	12/19/2017 6:53 PM
4	slow	12/19/2017 4:41 PM
5	Difficult set up of flow battery test systems	12/19/2017 4:13 PM

#	3.	DATE
1	Lack of MW level testing capabilities	12/28/2017 4:50 PM
2	Space constraints	12/19/2017 6:53 PM
3	expensive	12/19/2017 4:41 PM

Q17 If so, please identify it here:

Answered: 11 Skipped: 70

#	RESPONSES	DATE
1	New York Best	1/5/2018 3:16 PM
2	Exponent (self)	1/2/2018 6:10 PM
3	DNV GL Rodchester, NY	1/2/2018 12:13 PM
4	NY-BEST Test & Commercialization Center in Rochester, NY (at the Eastman Business Park, formerly Kodak); funded by NYSERDA (and users), operated by DNV-GL.	1/2/2018 12:08 PM
5	DNV GL's BEST Test & Commercialization Center (BEST T&CC)	1/2/2018 11:12 AM
6	Xilectric has done testing at cell level for corporations. there are many nationally (polaris, Umichigan, argonne, intertek, and several that support the detroit area). They typically charge a rate that is 3x the cost of the machine being used if you use it continually for a year (at least at a cell level). They typically do not have any expertise and run the program you suggest.	1/2/2018 10:45 AM
7	New York facility is to far away.	12/20/2017 2:00 PM
8	NY Best	12/20/2017 12:58 PM
9	NY BEST facility in Rochester, NY	12/19/2017 10:51 PM
10	Fraunhofer, 24M, NEC ES	12/19/2017 6:53 PM
11	RIT	12/19/2017 4:41 PM

Q19 What, if any, additional input would you like to provide about establishing a battery energy storage test facility in Massachusetts?

Answered: 22 Skipped: 59

#	RESPONSES	DATE
1	Testing islanded operation is of particular importance, due to the controls stability challenges, lack of standards, and value for energy resilience.	1/4/2018 3:34 PM
2	Since Vionx's technology is a vanadium redox flow system we have needs unique to flow batteries and so a testing facility in the Bay State would have to be equipped for such applications (as opposed to lithium ion in which the basic cell structures are all very similar).	1/3/2018 4:09 PM
3	Several states are pursuing some sort of battery test facility. There is already significant overcapacity in testing capability. It has reached the point that many bids to new solicitations are based on dismantling an existing test facility in another state and moving it. Resources are going towards moving equipment around instead of to testing. The barrier to testing is funding the construction of equipment to be tested and the labor for testing itself, not the availability of testing equipment.	1/2/2018 2:46 PM
4	If anything is built in MA, it should provide complementary, not redundant services to what is available at the NY-BEST facility in Rochester. While a small amount of overlap is acceptable, the centers should fully collaborate and use the unique strengths of each to the customer's (user and manufacturer) maximum advantage and least cost. MassCEC should develop a close relationship with NYSERDA and NY-BEST to leverage the States' capabilities, facilities, knowledge, and university expertise.	1/2/2018 12:08 PM
5	What about Thermal Energy Storage Systems to reduce or eliminate peak energy loads for chillers?	1/2/2018 11:59 AM
6	Ability to conduct large scale burn tests pursuant to UL9540A.	1/2/2018 11:12 AM
7	I would focus on large module/pack level testing, safety testing (nasty chemical/fire possibilities) such as nail puncture or thermal soaks, and grid integration (behind meter, infront meter). I don't think it makes sense to do cell level work. Most startups will have many channels already available as do most academic labs. High power or high current cyclers are expensive and typically out of reach of smaller companies.	1/2/2018 10:45 AM
8	I think having an independent testing facility could be an important resource for promoting this technilogy	1/2/2018 10:27 AM
9	In order to certify per IEC standard ,Provide universal supply voltage for testing grid interactive inverter, US and Europe. Insure the simulated grid can absorb and inject power swiftly. The simulated grid can provide leading and lagging power factor,	1/2/2018 10:16 AM
10	The key test question is linking battery capabilities to economic value creation. Very little has been done in this area.	1/2/2018 10:04 AM
11	Please make sure there is a system control that will accommodate hardware in the loop. We would want to swap different inverters or converters and simulate solar shaping variations.	12/28/2017 4:50 PM
12	All testing must insure privacy of test results during the development phase. We need to test and then improve our product in a confidential environment.	12/20/2017 2:00 PM
13	Technologies are mature and by the time a test facility is established, they will already be tested multiple times at other places. Testing at a required facility will slow down the integration of storage on the grid. This is most useful for start up storage manufacturers with new technologies that are pre-commercial.	12/20/2017 12:58 PM
14	While I understand what is driving this survey, it does not take into account the emerging hydrogen energy storage activities and use of FCV as refillable energy storage platforms. Refer to H2@Scale U.S. DOE programs operating out of NREL.	12/20/2017 8:44 AM