Workshop on Energy Storage Systems and the Built Environment

PROCEEDINGS

HELD:

19 November 2015 in New York, New York

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Quincy, Massachusetts, USA

Hosted by the Fire Department of New York

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Executive Summary

These are the proceedings of a workshop to address Energy Storage Systems (ESS) in the built environment, including installation and firefighting practices. The summary observations provide key observations from discussions and presentations and are organized into 5 categories:

- General
- Hazard Characteristics
- Standards
- Built-In Fire Protection
- Manual Fire Fighting

Electrical ESS are generally proliferating in the marketplace, with uses such as supporting alternative energy applications (e.g. photovoltaic systems, wind turbines, etc.) in a variety of building types. Systems have a diversity of configurations and variability of factors with unique features. One unique hazard is stranded electrical energy which presents both a shock hazard to personnel and potential re-ignition of the battery.

This workshop was focused on discussion to help guide the building regulatory community and fire departments in evaluating ESS technology, the applications for the installation of ESS and inform firefighting practices. Breakout groups addressed questions on three aspects of ESS in the built environment: building design features such as ventilation and fire separation, built-in fire protection systems including detection and suppression, and manual fire fighting practices including overhaul.

Post-fire operations pose one of the largest concerns and is a current gap in research because of stranded energy within the battery. Standard energy poses electrical and re-ignition hazards to responders and salvage personnel. The extended timeline of incidents and responsibilities of safe removal and disposal need to be addressed.

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Acknowledgements

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This workshop summary report has been prepared by Daniel Gorham, Research Project Manager for the Fire Protection Research Foundation. The information contained herein is based on the input of numerous professionals and subject-matter-experts. While considerable effort has been taken to accurately document this input, the final interpretation of the information contained herein resides with the report author. The content, opinions and conclusion contained in this report are solely those of the author and do not necessarily represent the views of the Fire Protection Research Foundation, NFPA, Technical Panel or Sponsors. The Foundation makes no guarantee or warranty as to the accuracy or completeness of any information published herein. The Foundation makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

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About the Fire Protection Research Foundation
The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)
Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. All NFPA codes and standards can be viewed online for free. NFPA's membership totals more than 65,000 individuals around the world.

Keywords: Energy Storage System, ESS, lithium-ion battery, flow battery

Table of Contents

List of Figures

1) Background and Overview

The application of electrical energy storage systems (ESS) using technologies such as bulk lithium-ion and flow batteries has proliferated in recent years and is steadily increasing. The intended deployment of ESS in the built environment is focused on the public and private sector, new and existing buildings, and in occupancies such as high rise structures as well as single and multi-family residences. Local Authorities Having Jurisdiction (AHJs) and emergency responders, along with ESS integrators, installers, insurers and others, are challenged by the lack of a clear understanding of the overall hazard associated with ESS and optimum approaches to addressing the hazard. Such approaches include the appropriate built-in fire protection measures and emergency responder strategies and tactics. Currently, New York City has already seen more than 100 applications to install ESS in varied structures.

The workshop goal was to utilize the New York City experience as a case study and develop a workshop report to help the NYC Building Department and FDNY in evaluating applications for the installation of ESS, and inform firefighting practices. New York City Fire Department Commissioner Daniel Nigro provided opening remarks for the workshop participants, expressing the importance of the work they are doing.

Figure 1: FDNY Commissioner Nigro addressing the workshop participants.

Figure 2: Panel and moderator (Casey Grant, FPRF) during the plenary discussion.

The workshop agenda consisted of three main parts: baseline presentations, break-out groups, and summary observations. The baseline presentations were given from a range of perspectives in the ESS industry and provided all participants with a review of the current state of the topic followed by a plenary discussion with the panel and all attendees. Workshop participants were placed into one of three break-out groups to have a more in-depth discussion on their focus topics and provide answers to the questions. At the end of the day all three groups reconvened to provide the full group with a summary of their discussion. A copy of the workshop agenda is shown in Figure 3.

Breakfast provided by Con Edison		0730
Call to Order @ 0800: Overview of Workshop Goal and Objectives	All	0800
Baseline Presentations with Panel Discussion	Panel	
Codes, Standard, Regulations	Dave Conover, PNNL	0830
First Responder Safety	Dave Rosewater, Sandia National Lab	0840
Fire Fighting Operations	Paul Rogers, FDNY	0850
NYC Energy Policy	Wendy Wan, NYC Buildings Department	0900
Building Managers	Jack Murphy, FSDANY	0910
Technology Trends	Andrew Blum, Exponent	0920
ESS Providers	Roger Lin, NEC Energy Solutions	0930
Utilities	Britt Reichborn-Kjennerud, Con Edison	0940
Research	Celina Mikolajczak, Tesla	0950
Plenary Discussion (with Panel)	All	1000
Break provided by Con Edison		1030
Overview of Break-Out Groups and Review of Priority Topic Areas	All (& Break-Out Groups)	1045
Group 1: Facility & Building Design Features / **Group 2: Built-In Fire Protection Systems** / **Group 3: Emergency Response Strategies and Tactics**		
Con Edison Demand Management Program		1145
Lunch provided by Con Edison		1200
Break-out Groups Continue	All (in Break-Out Groups)	1300
Break provided by Con Edison		1415
Break-out Group Reports & Plenary Discussion	All	1430
Workshop Re-cap and Summary Observations (Adjourn at 1600)	All	1530

Figure 3: Workshop agenda.

2) Discussion on Needs

2.1) Background

Three break-out groups (Figure 4) were developed to cover important discussion points of ESS in the built environment. Group 1 covered the topic of facility and building design features including passive systems, construction type, separation and egress. Group 2 covered built-in fire protection systems including detection, notification, and automatic suppression systems. Group 3 covered emergency response strategies and tactics, including pre and post-incident. Workshop participants were distributed into the three groups based on their knowledge and experience. An attempt was made to provide representation from all interests in each group.

Group 1: Facility & Building Design Features

- Passive Systems
- Separation
- Egress

Group 2: Built-In Fire Protection Systems

- Active Systems (detection, suppression, etc.)

Group 3: Emergency Response Strategies & Tactics

- Pre & Post event

Group 1	Group 2	Group 3
Dave Conover (Facilitator)	Andrew Blum (Facilitator)	David Rosewater (Facilitator)
Chris Dubay	Andrew Klock	Ken Willette
Jeff Sargent	Rich Bielen	John Caufield
Kevin McGrath	Chris Rogan	Celina Mikolajczak
Ronald Butler	Bill Meyring	Benjamin Marshall
Thomas Jensen	Randy Fish	Chris Moynahan
Rob Neale	Nicholas Warner	Richard Bhlom
Jack Lyons	Joseph Razza	Matt Paiss
Jason Doling	Benjamin Ditch	Vincent Adinkrah
Stan Andrzej Skoskiewicz	Jack Murphy	Jose Canales
Anostere Jean	Roger Linn	Bruce Johnson
John Cangemi	Jeremy McDonald	Britt Reichborn-Kjennerud
Justin Perry	Mike Oreskovic	Amaury De La Cruz
John Cerveny	Jacob Millan	Paul Rogers
Jin Jin Huan	Thomas Chapin	Nicholas Delre
Tamara Saakian	Terrance Waldron	Paul Cresci
Nick Petrakis	Milissa Marona	Robert Ingram
Charles Joyce	Edward Ferrier	Russel Strobel
Wendy Wan	Leo Subbarao	Ben Goss
Gil Moniz	Cindee Tripodi	
Matt Daelhousen		

Figure 4: Break-out groups.

2.2) Questions

The questions, seen in Figure 5, were developed to support the workshop goal of creating a report to assist building and fire departments in handling ESS installation applications and inform firefighting practices. Each group was assigned a focus issue (facility & design, built-in systems, and emergency response) with specific questions but also had the opportunity to address all focus issues.

I) Overview and Hazard Assessment
a. What are the primary concerns with current practices and future trends?
b. Are there important literature, codes and other documents not already mentioned?
c. Are there case study events not already mentioned (generically) that are important?
d. What are the regulatory gaps, and their priority?
e. What are the research gaps, and their priority?
f. What other gaps are important, and their priority? (e.g., advocacy, Edu, training, data, etc...)?

II) NYC Building and FD Concerns for ESS			
Focus Issues (each group will report on their topic)	Group 1: **Facility & Building Design Features** (i.e., passive systems, separations, egress, etc)	Group 2: **Built-In Fire Protection Systems** (i.e., active systems such as fire suppression & detection, etc)	Group 3: **Emergency Response Strategies & Tactics** (w/ pre & post event)
a. What are the current codes and standards available to install and permit ESS?	X	X	
b. What are the appropriate passive systems for ESS (fire separations, location, egress, signage, etc)?	X		
c. What type of fixed fire extinguishing systems are appropriate (for the building and for the ESS modules)?		X	
d. What type of fire detection systems are appropriate?		X	
e. How should the ESS be ventilated?	X	X	
f. How is spill containment achieved and what should the HazMat response be?			X
g. What are safe firefighting operations (interior/exterior attack, safe distance, electrical disconnect, manual suppression methods)?			X
h. How do you currently permit, protect and respond to similar hazards such as electrical switch gear rooms, uninterruptable power supply systems, photovoltaic systems, wind farms, etc?	X	X	X

III) General
a. What are the key messages for policy-makers on this topic? (i.e.., what are the most important considerations to support the successful proliferation of ESSs?
b. What constituent groups should also be included in future efforts to address this topic?
c. What other issues should be addressed, not already addressed here by other questions?

Figure 5: Break-out group questions.

2.3) Break-out Group Discussion Summary

After the break-out sessions, all workshop participants regrouped to review their group discussions. Each break-out group had an appointed facilitator who presented their group report. Section 2.3.1 through 2.3.3 provide a summary of each report.

2.3.1) Group 1

The Group 1 report facilitator provided the following overview summary:

Energy storage systems are a rapidly changing technology and marketplace. There is currently no central repository for data and information, something needed for proponents to make available their information. Product standards are becoming available but there is an immediate need for integrated application guidance, which could include installation standards and building regulatory (e.g. building, electrical, fire codes) considerations.

Adoption of current and future codes and standard need to be a priority for regulatory agencies and other AHJs because they contain references to the new technology. Jurisdictions need to be made aware of the importance of adopting codes and standards that consider new technology. All interested parties and stakeholders should collaborate to develop a consensus on the issues and participate in the codes and standard development process.

Manufacturers may be less inclined to share proprietary information on new technology that is critical to updating codes and standards. There needs to be a balance between bringing the new technology to the market quickly and preparing for future changes and issues. All of the issues and concerns for the technology use may not be known at installation. If a conservative approach (e.g. erring on the side of safety) is used initially, proponents will be more likely to conduct research and provide answers to issues and concerns.

The connection and interaction with the energy generation should be considered in the overall system evaluation. Localized energy generation include photovoltaic and other renewable sources effect the hazards associated with ESS.

Installation and product standard should not become applications engineering. Passive fire protection systems (fire separation, location, egress, signage, etc.) are dependent on how different ESS types and chemistries perform in fire situations. A conservative approach initially for review of installation applications will encourage research in determining how systems will perform in these situations.

Uninterruptable Power Supply (UPS) systems with significant storage capacity (4-hours) may provide needed documentation for addressing the safety of an energy storage system. The fire protection features and hazard mitigation techniques from UPS could provide a foundation for ESS criteria.

Thermal runaway is a concern for lithium-ion ESS because of the fire intensity and toxicity hazards. Determination of when systems are prone to runaway based on use, charging/discharging rate which may be dependent on the time of day. The cycling time of a system needs to be considered, as well as normal and abnormal conditions. The questions is not “if” a runaway event will occur but “when”. Design and pre-incident planning should consider normal, abnormal, and intentional events.

2.3.2) Group 2

The Group 2 report facilitator provided the following overview summary:

Jurisdictions should use current codes and standards that include new technology relevant in ESS installation. Product standards for ESS technology, such as UL 9540, currently under development by Underwriter's Laboratories, should be included and considered in the siting and review of installation applications.

System categorization is currently being done based on user conditions, energy capacity (kilowatt-hours). For risk assessment purposes ESS would be better categorized by technology and chemistry because the hazards are significantly different between them. With the proliferation of varying ESS technologies and or battery chemistries it may not be practical for the fire and building codes to address each of these, especially given the pace at which new types of systems are introduced and/or brought to the market. A more practical approach for building and fire codes could require the ESS to be listed to a design standard, such as UL 9540 once it is published, and then address room/building safety features around that listed ESS. With a listed ESS, the performance of the ESS in regards to fire and electrical hazards will be known and therefore the fixed fire suppression, detection and ventilation systems can be designed to protect the anticipated hazard. By not requiring a listing each ESS design, technology, and installation would need individual scrutiny and potentially, considerable analysis; something that could slow down the installation of these systems and their success in the marketplace.

The concept of system (box) and enclosure (room) is important when considering built-in protection systems. For instances, which built-in fire protection systems (suppression, detection, and ventilation) are required for the ESS cabinet (or box) and which are necessary for the enclosure (or room) in which it is installed within?

Fixed-automatic suppression systems will likely play an important role in fire protection for ESS installations. The type of system and suppression agent will be dependent on the ESS classification based on technology, chemistry and system design, which could incorporate a number of additional fire and electrical safety features. Manufacturers of ESS need to work with fire suppression manufacturers to determine compatible system and suppression agents.

Early detection is important for fire hazard, allowing time for mitigation including notification (evacuation and fire department), suppression, and ventilation. Current building codes require smoke detection in battery storage rooms. Other detector technologies, including heat and combustible gas may offer earlier detection. Internal ESS sensors may provide information about system status (temperature) and early warning of potential fire. Having the ability to tie these internal ESS sensors into the Fire Alarm System or the Fire Command Center is integral in early detection and response to an ESS incident.

Combustible and toxic gases produced pose a hazard and need to be ventilated safely. Some ESS (box) have ventilation designed to off-gas to the enclosure (room). The room would then need to be ventilated. Consideration needs to be given for the types of gases produced and separate ventilation from building HVAC systems as well as potential interaction with the activation and effectiveness of suppression systems with these operating ventilation systems.

2.3.3) Group 3

The Group 3 report facilitator provided the following overview summary:

The lifeline of an ESS, from the siting and installation to decommissioning and removal of hazard from the building should be managed continuously by the building owner or property manager.

Installation should include clear identification and marking with a system like the hazard placard set in NFPA 704. These markings should be made on the outside of the building and at the enclosure (room) entry. An emergency shutoff needs to be provided for firefighters when responding to an emergency. The emergency shutoff should isolate the energy and shut down the system completely. Important information on the status of the system should be communicated to the fire department in the event of emergency. This information should include: voltage, error warnings, automatic extinguishing systems discharge status, battery conditions (temperature), chemical leakage, and automatic ventilation status.

When firefighter respond to an emergency they should use the critical incident dispatch system (CIDS) to determine appropriate actions. The hazard type of the emergency should first be established: is there a fire? In a situation where there is a fire: is the ESS involved in the fire? The status of the battery, including voltage and temperature should be considered. If there are automatic suppressions systems have the discharged? Visual and audible cues provide pertinent information about the situation, but personnel safety should not be compromised: is there a video feed available?

Based on the risk assessment performed during the CIDS questioning, and if there is a fire, responders should determine if the fire should be extinguished. The effect of action on the system in question should be considered for other systems (ESS, others).

3) Summary Observations

3.1) Overview

The Workshop on Energy Storage Systems and the Built Environment provided an opportunity for a diverse set of stakeholders to discuss energy storage systems. This one-day workshop provided a medium for discussion that was intended to help guide jurisdictions in evaluating applications for the installation of ESS and inform firefighting practices.

Concerns about energy storage systems have been confirmed and this technology will continue to proliferate based on demands. Practices such as peak shaving are being used to regulate the supply and demand of energy around the world. An example of the proliferation of this technology is shown in New York City where the building department has seen the more than 100 applications to install ESS in varied structures in the past year.

Innovation in storage technology is moving fast, and energy storage systems are evolving rapidly. This is important for energy needs and concerns but makes hazard mitigation difficult, as new technology comes into the market place the safety concerns are not always adequately addressed.

A panel of subject matter experts provided baseline presentations on energy storage systems from a variety of perspectives. Workshop participants came from a varied cross-section of interested stakeholders include insurers, manufacturers, building owners, and first responders.

Workshop participants were distributed into break-out groups, with participants from the cross-section of interested stakeholders. The three break-out groups: Facility & Building Design Features, Built-In Fire Protection Systems, and Emergency Response Strategies and Tactics, addressed general questions on ESS and specific questions to the group topic. The methodology for discussion amongst the three groups was as varied as the participants, some marching through the break-out questions while others discussed the topic in chronological order of ESS lifespan.

Several other projects on energy storage systems are currently on-going and were discussed. In addition to this workshop, the Fire Protection Research Foundation is conducting a project on the *Hazard Assessment of Lithium Ion Batteries used in Energy Storage Systems* and a S*prinkler Protection Criteria for Lithium Ion Batteries Stored in Cartons*. NFPA is developing training material for first responders on the hazards and emergency response considerations for energy storage systems. Other groups are conducting research and projects on different battery types and chemistries to determine fire and other hazard characteristics. The Department of Energy has several work groups addressing issues and concerns with ESS in the built environment.

3.2) General Concepts

Several general concepts came out of discussion during the workshop. One was the scale and location of ESS in the built environment. The systems themselves often contain many cells, which are clustered into modules. The battery modules are stored in trays that are contained within the system rack. This is the first primary scale in the built environment where the shell can have fire protection systems such as detection, suppression, and ventilation. Within a building the rack can be contained inside a room that provides barrier separation from the hazard. This provides protection of the ESS from exposure fire conditions as well as insulating the system from the rest of the floor. A floor within the building may contain several racks and act as an enclosure from the rest of the building. Fire protection systems such as detection, suppression, and ventilation should also be considered for the room and floor the systems are in. Systems are outside of the building, such as on the roof or in an area away from the building, pose an exterior exposure. Roof-top mounted systems may have a direct exposure to the building while systems separated from the building may pose only a limited exterior exposure. Figure 6 shows the scale of ESS and exposures within the built environment.

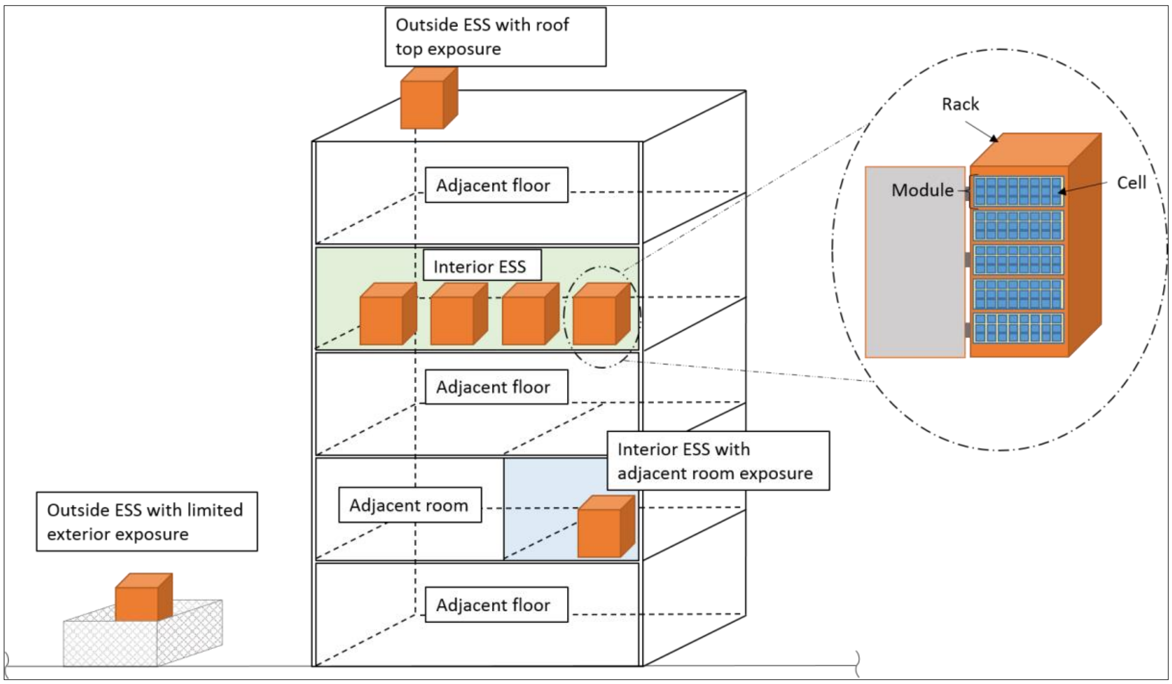

Figure 6: Scale and location exposures of ESS in the built environment.

The timeline of an ESS in the built environment is an important consideration. Considering the three stages of an emergency event associated with ESS, the timeline for the systems and actions are shown in Figure 7. Incident consideration begins with the siting and installation of the system. The intiation of an incident starts with the detection of conditions that pose a hazard to or from the ESS. Automatic systems, including notification, suppression, and ventilation begin while emergency responders are enroute. Manual operations include rescue, suppression, and ventilation. After the fire has been controlled, overhaul operations begin, which include monitoring for hazardous material situations and observing the ESS for the possiblity of rekindling. A unique feature of ESS systems is the ability to store stranded energy, which inherently is an electrical and fire hazard. One of the major concerns for incidents involving ESS is the extended timeline based on the nature of the system. It is currently unclear who is responsible for the safe disposal and removal operations after an incident.

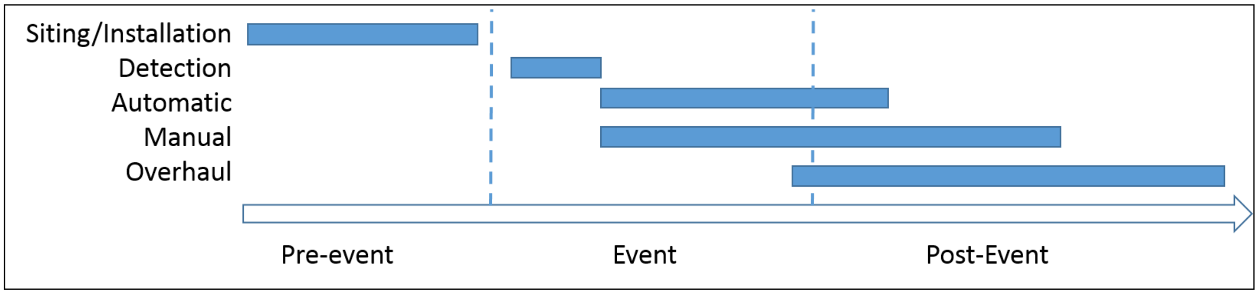

Figure 7: ESS lifespan timeline.

3.3) Key Observations

The following are the specific summary observations from the ESS workshop, based on the presentations, general and break-out group discussion:

General

- Increasing Applications: System installations of electrical ESSs are generally proliferating, and marketplace installations are expected to increase based on high consumer demand and limited energy supplies.
- Support for Alternative Energy Sources: Energy storage is a key supporting technology for certain alternative energy applications (e.g., photovoltaic systems, wind turbines, etc.) that are not able to generate electrical energy on a constant basis. As these increase in application, so too will electrical ESS.
- On-Site Applications: Available technology makes electrical ESS an attractive option for all levels of end-users, from small single family residential applications to large commercial high-rise buildings.
- Similar Applications: There are already certain applications that are similar to electrical ESS installations, such as UPS systems that utilize conventional lead-acid battery back-up, and although different they offer useful parallels for safety-oriented approaches.
- Categorization: Systems are currently categorized by storage capacity (kilowatt hours). Potential methods for categorization include: chemistry, productions of combustion, and runoff.

Hazard Characteristics

- Hazard Understanding: The hazards of each specific application are not fully known or understood.
- Evolving Technology: The technology is constantly evolving and is not steady-state, continually introducing new enhanced approaches that also have hazard characteristics that are not fully understood.
- Diversity of Configurations: Each type (e.g., model of equipment) of installation is relatively unique and this diversity is a challenge for assuring a safe installation.
- Variability of Factors: The technology is not easily categorized because of the variability of all applicable factors. For example, the hazard characteristics of a single battery type (e.g., Lithium-Ion) can vary dramatically based on other factors such as geometry, configuration, air-cooled versus liquid-cooled, size, housing materials, state of charge, battery management system, etc.

- <u>Unique Features:</u> Concerns for electrical ESS include: intense thermal exposure; electrical shock; hazardous materials and contaminants; stranded electrical energy causing re-ignition; and other factors (e.g., access depending on geometry, etc.).
- <u>Time Dependency:</u> A unique hazard of electrical ESSs using batteries is the problem of stranded electrical energy, which can cause a fire ground scene to be considered unsafe for long periods of time (e.g., days, and even weeks) due to thermal runaway causing re-ignition long after the fire is fully extinguished in accordance with all traditional forms of measurement.

<u>Standards</u>

- <u>Safety Standardization:</u> Providing standardized approaches for addressing safety is critical for the continued safe proliferation of this technology.
- <u>Application Specific:</u> Specific best practice application oriented information is needed for emergency responders, end-users, code officials, etc.
- <u>Performance-Based:</u> Installation standard may want to consider a performance-based approach to allow for rapidly changing technology and innovation.
- <u>Environmental Impact:</u> Runoff and spillage of ESS poses environmental risk based on chemistry and volume spilled and environmental protection needs to be incorporated in installation, maintenance, incident response, and decommissioning.

<u>Built-in Fire Protection</u>

- <u>Customization:</u> Fire protection systems will need to be specifically designed and installed for the particular electrical ESS they are protecting.
- <u>Detection/Sensors:</u> Smoke and heat detection in energy storage rooms are important for minimizing fire hazard and required by ICC and NFPA 1 for battery rooms. Internal sensors (temperature, voltage) can provide early warning of a system entering a non-normal state.
- <u>Fire Suppression Agent:</u> A single extinguishing agent with universal applicability for electrical ESSs is not obvious, and different agents may ultimately provide optimum protection characteristics depending on the specific application they are protecting.
- <u>Ventilation:</u> The design and functionality of the ventilation system will be critical for manual firefighting efforts if needed. Where the system is ventilated will be important based on off-gas hazards and system location.

<u>Manual Fire Fighting</u>

- <u>Site Location:</u> The final installation is a critical consideration for manual firefighting efforts. For example, systems located on the upper floors of a high-rise building present a much greater concern than in an isolated one-story structure without exposures.
- <u>Overhaul:</u> Post-fire handling of damaged ESS equipment is a special concern, and in particular dealing with stranded electrical energy from damaged batteries with inoperative battery management systems and electrical connections.
- <u>Suppression:</u> Copious amounts of water has shown to be effective for most ESS. Chemistry specific suppressants will need to be considered for batteries that are reactive with water.
- <u>Electrical Discharge:</u> Voltage leakage hazard through a fire hose water stream can be mitigated by sufficient distance between responder and energy source. The separation of systems within a building will need to consider this.
- <u>Personal Protective Equipment:</u> Hazardous materials released from systems may require additional protection beyond structural firefighter PPE and decontamination of equipment.

- Spill Containment: The chemistry and volume of spilled material dictates containment strategy, which also must consider environmental impact.
- Non-fire incident: Where the ESS itself is not involved with a fire, it should be protected from external exposure because of hazard potential.
- Battery Management System: Information on the system status and battery state of charge is important for guiding firefighter practices. System shutdown and battery discharge may not be an option during an incident because of critical operation functions of ESS systems in data storage operations.

3.4) Future Opportunities

Energy storage systems in the built-environment are still a new topic and pose several opportunities moving forward.

3.4.1) Research

There are still many questions on the performance of automatic suppression systems for different battery chemistries and system designs. Stranded energy within system batteries has been identified in this and previous work as a hazard for first responders and system maintainers. Future work could help better understand this hazard and mitigation techniques.

3.4.2) Standards

Current codes and standards are being revised to incorporate energy storage systems. Several groups have identified the need for a standard on siting and installations of ESS in the built environment.

3.4.3) Training

Training with all groups including responders, manufacturers, and installers/maintainers should be developed and disseminated.

3.4.4) Advocacy

The prevalence and proliferation of ESS is an important component in the energy industry. It will be important to advocate for safe implementation of these systems in the built environment.

Annex A: Workshop Participants and Attendees

The following were attendees at the Workshop on Energy Storage Systems and the Built Environment, held in FDNY's Randall's Island, New York City, NY on 19 November 2015.

Name	Organization
Vincent Adinkrah	Storage Power Solutions Inc.
John Alston	JCFD
Stan Atcitty	Sandia National Laboratories
Edward Bergamini	FDNY
Richard Bielen	NFPA
Andrew Blum	Exponent
Ronald Butler	ESSPI
Jose Canales	Thornton Tomasetti
John Cangemi	UL LLC
John Caufield	NFPA
John Cerveny	NY-BEST
Thomas Chapin	UL LLC
Dave Conover	Pacific Northwest National Laboratories
Matt Daelhousen	FM Global
Amaury De La Cruz	Con Edison
Nicholas DelRe	FDNY
Benjamin Ditch	FM Global
Jason Doling	NYSERDA
Chris Dubay	NFPA
Edward Ferrier	FDNY
Randy Fish	California Energy Storage Alliance
Daniel Gorham	NFPA
Ben Goss	Waldron Engineering of New York
Casey Grant	NFPA
Megan Housewright	NFPA
Jin Jin Huang	Con Edison
Jonathan Ingram	Kiddie Fire Systems
Robert Ingram	FDNY
Bruce Johnson	UL LLC
Charles T. Joyce P.E.	FDNY
Andrew Klock	NFPA
Andres Ledesma	Con Edison
Roger Linn	NEC Energy Solutions

Jack Lyons	NEMA
Benjamin Marshall	FM Global
Jeremy McDonald	Southwest Research Institute
Bill Meyring	3M
Celina Mikolajczak	Tesla Motors
Jacob Millan	Tesla Motors
Gil Moniz	NFPA
Chris Moynahan	Greenwich Fire Dept
Jack Murphy	FSDANY
Julie Nacos	Columbia University
Anthony Natale	Con Edison
Rob Neale	International Code Council
Dan Nigro	FDNY
Mike Oreskovic	Storage Power Solutions Inc.
Matt Paiss	San Jose Fire Department/NFPA
Justin Perry	Dominion Resources Services Inc.
Nick Petrakis	FDNY
Joseph Razza	Fire Engineer
Britt Reichborn-Kjennerud	Con Edison
Chris Rogan	Eaton Engineering
Paul Rogers	FDNY
Jesse Roman	NFPA
David Rosewater	Sandia National Laboratory
Tamara Saakian	FDNY
Jeff Sargent	NFPA
Alison Silverman	Sustainable CUNY
Scott Springer	Con Edison
Chuck Stravin	NFPA
Russell Strobel	FDNY
Leo Subbarao	FDNY
John Sudnik	FDNY
Cindee Tripodi	FDNY
Wendy Wan	NYC Buildings Department
Brandon Ward	Con Edison
Nicholas Warner	DNV GL
Carlton White	Con Edison
Ken Willette	NFPA

Annex B: Short Bios of Panel Members

Chris Dubay, Chief Engineer, NFPA

Christian Dubay is Vice President, Codes and Standards and Chief Engineer at NFPA. Dubay oversees all the codes and standards related activities, including Electrical Engineering, Fire Protection Applications & Chemical Engineering, Public Fire Protection, Building & Life Safety, and Codes & Standards Administration.

Daniel A. Nigro – Commissioner, FDNY

Daniel A. Nigro is the Commissioner of the New York City Fire Department (FDNY). Nigro's appointment was announced on May 9, 2014, and he was sworn in on June 9, 2014. Nigro is the 33rd Commissioner in the 150-year history of the New York City Fire Department. The Commissioner is the most senior member of the fire department. Nigro joined the FDNY in 1969. He became a Deputy Chief in 1993, and in 1996, he oversaw the merging of the city's ambulance squads with the fire department. Nigro was appointed Chief of the department—the highest-ranking uniformed position—following the death of Chief Peter J. Ganci, Jr., in the 9/11 attacks.

Dave Conover, PNNL

Dave Conover has graduate and undergraduate degrees in Mechanical Engineering from the Catholic University of America. He has been involved with the development, adoption, implementation and enforcement of building construction regulations, focused primarily on energy use and technology acceptance, since 1976. During his 34 years of involvement with the building industry at the global, national and local level he has held positions with the American Gas Association, the National Conference of States on Building Codes and Standards, the International Code Council and PNNL. He also served as the CEO of the National Evaluation Service, a subsidiary of the three organizations who formed the ICC, focusing on evaluation of new technology for acceptance within building regulatory programs. At PNNL he is currently focusing on all aspects of energy codes and standards. He is actively involved with ASHRAE and currently serves as a member of the ICC committee drafting the ICC green construction code. He is an active triathlete and serves as a CAT 1 race official for USA Triathlon. Prior to starting his career in buildings he worked in the rail industry; one project of which was the design of the first insulated rail car to bring Coors beer to the East Coast in the early 70’s.

Dave Rosewater, Sandia National Lab

David M. Rosewater is an Energy Storage Test Engineer at Sandia National Laboratories. Mr. Rosewater is a key member of the Sandia Energy Storage Safety Validation team where he uses the US Department of Energy’s Energy Storage Test Pad (ESTP) located at Sandia National Laboratories to characterize AC integrated energy storage systems up to 1MW in size. Mr. Rosewater holds a Professional Engineering license in the state of New Mexico with a specialty in electrical power engineering. Prior to moving to the stationary energy storage sector at Sandia National Laboratories in 2011, Mr. Rosewater spent three years working with the Idaho National Laboratory developing advanced spectral impedance measurement techniques for hybrid vehicle batteries. He obtained his master's degree in electrical engineering from Montana Tech.

Paul Rogers, FDNY

FDNY Lieutenant Paul Rogers has been with the New York City Fire Department since 1993. As an FDNY officer, Lieutenant Rogers is a Fire Prevention Subject Matter Expert (SME) for the FDNY Special

Operations Command (SOC) Hazardous Materials Operations Unit. Lieutenant Rogers serves on the FEMA Urban Search and Rescue Task Force (USAR) NYTF 1 as a Hazardous Materials Manager. Lt. Rogers also serves as an FDNY liaison to the U.S. Marine Corps Chemical Biological Incident Response Force (CBIRF). He is a voting member representing first responders for National Fire Protection Association (NFPA) 1991,1992, and 1994 in the development of national standards for chemical protective clothing (CPC) used by first responders/industry. Lt Rogers is the FDNY representative on the Office of Technical Certifications and Research for Energy Storage Systems (ESS) within the New York City Department of Buildings. Lt. Rogers has also participated in numerous projects for the National Grid, Consolidated Edison, AT&T and Kinder Morgan within the renewable energy sector and the development of standards, codes and regulation related to first responders. He has written several articles on renewable energy and first responder/safety issues including "Responses to Energy Storage Systems," published in the June 2015 issue of ***Fire Engineering***.

Wendy Wan, NYC Buildings Department

Wendy Wan, RA, is a Code Development Architect at NYC Department of Buildings. She was previously at NYC Dept. of Design and Construction, Stephen B Jacobs Group, and Superstructures Engineers + Architects. Wendy is a Registered Architect with the State of New York, a LEED Accredited Professional with the US Green Building Council, and a Certified Energy Manager with the Association for Energy Engineers. She completed her college education at the University of Texas at Austin.

Jack Murphy, FSDANY

Jack J. Murphy, MA, is a fire marshal (ret.) and a former deputy chief. Currently he serves as COO of eBIC Preparedness Solutions and Chairman of the New York City Fire Safety Directors Association. He is a member of the NFPA High-Rise Building Safety Advisory Committee and the 1620-Pre-Incident Planning Committee. Over the years, he has published various fire service articles. He is a Fire Engineering Magazine contributing editor, a PennWell Fire Group executive advisory board member, and he has received the 2012 Fire Engineering 'Tom Brennan' Lifetime Achievement Award.

Andrew Blum, Exponent

Mr. Andrew Blum is a Managing Engineer in Exponent's Thermal Sciences practice. He is a Registered Professional Engineer in the states of Maryland, Georgia and Florida, and is a Certified Fire and Explosion Investigator (CFEI) in accordance with the National Association of Fire Investigators (NAFI). Andrew is a member of numerous ASTM, ICC and NFPA committees, and he received a BS and MS degrees in Fire Protection Engineering from the University of Maryland.

Roger Lin, NEC Energy Solutions

Roger Lin is Director of Product Marketing at NEC Energy Solution. He has a Bachelor of Science degree in Ceramics Engineering from Rutgers University-New Brunswick, and a Master of Engineering in Materials Science and Engineering from Massachusetts Institute of Technology. He previously worked at A123 Systems, YankeeTek Ventures, and Saint-Gobain Corporation.

Britt Reichborn-Kjennerud, Con Edison

Britt Reichborn-Kjennerud is a Research & Development Specialist at Con Edison, where she designs and manages projects that introduce new technologies into the company's infrastructure and operations. She was a NSF Astronomy and Astrophysics Postdoctoral Fellow at the Columbia University Astrophysics Lab. Britt has a B.A. in Astronomy from Yale University, a M.A. in Philosophical Foundations of Physics from Columbia University, and a Ph.D. in Physics also from Columbia University.

Annex C: Workshop PowerPoint Slides

Figure 8: Presentation by David Rosewater (1 of 5)

Figure 9: Presentation by David Rosewater (2 of 5)

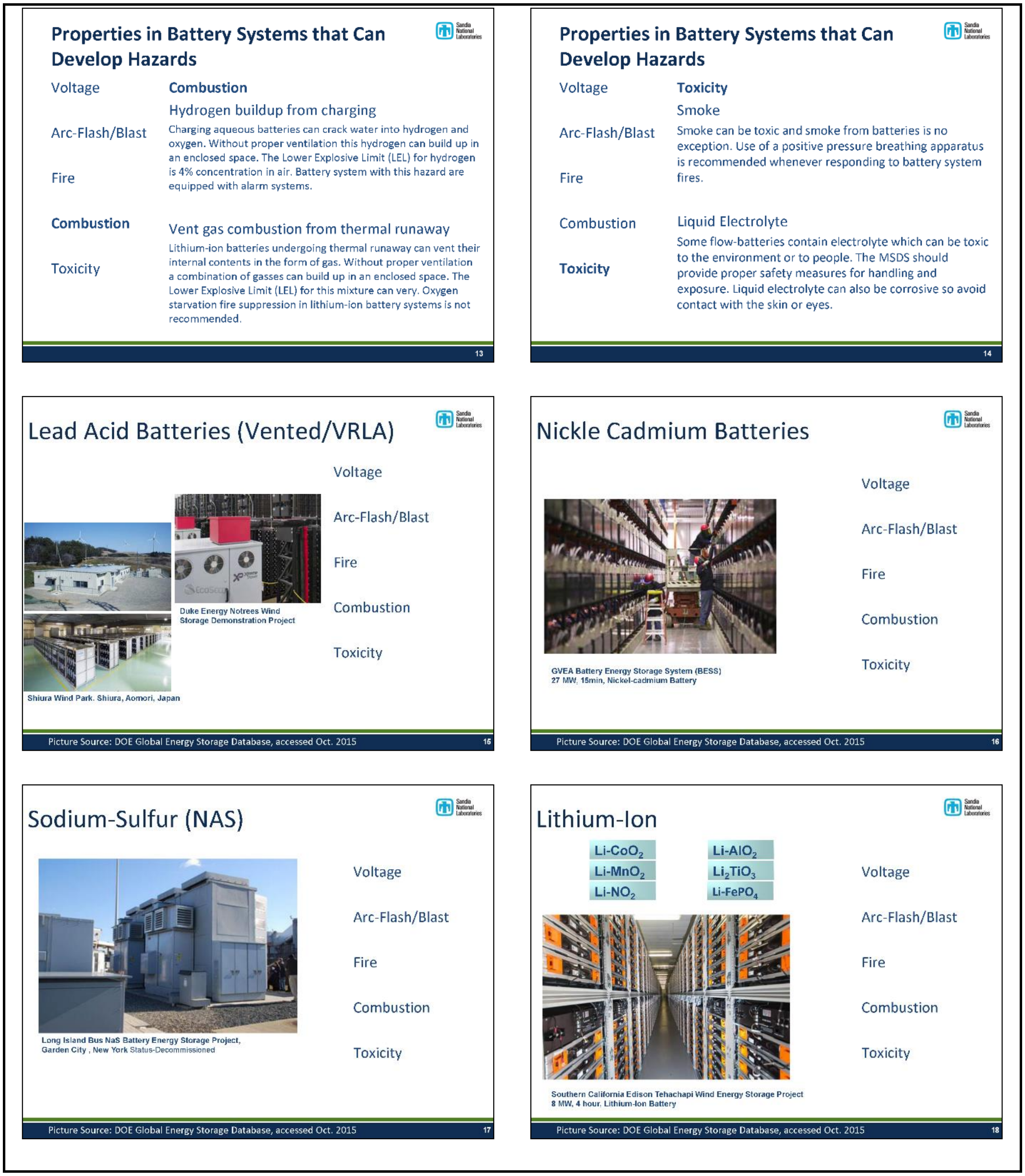

Figure 10: Presentation by David Rosewater (3 of 5)

Figure 11: Presentation by David Rosewater (4 of 5)

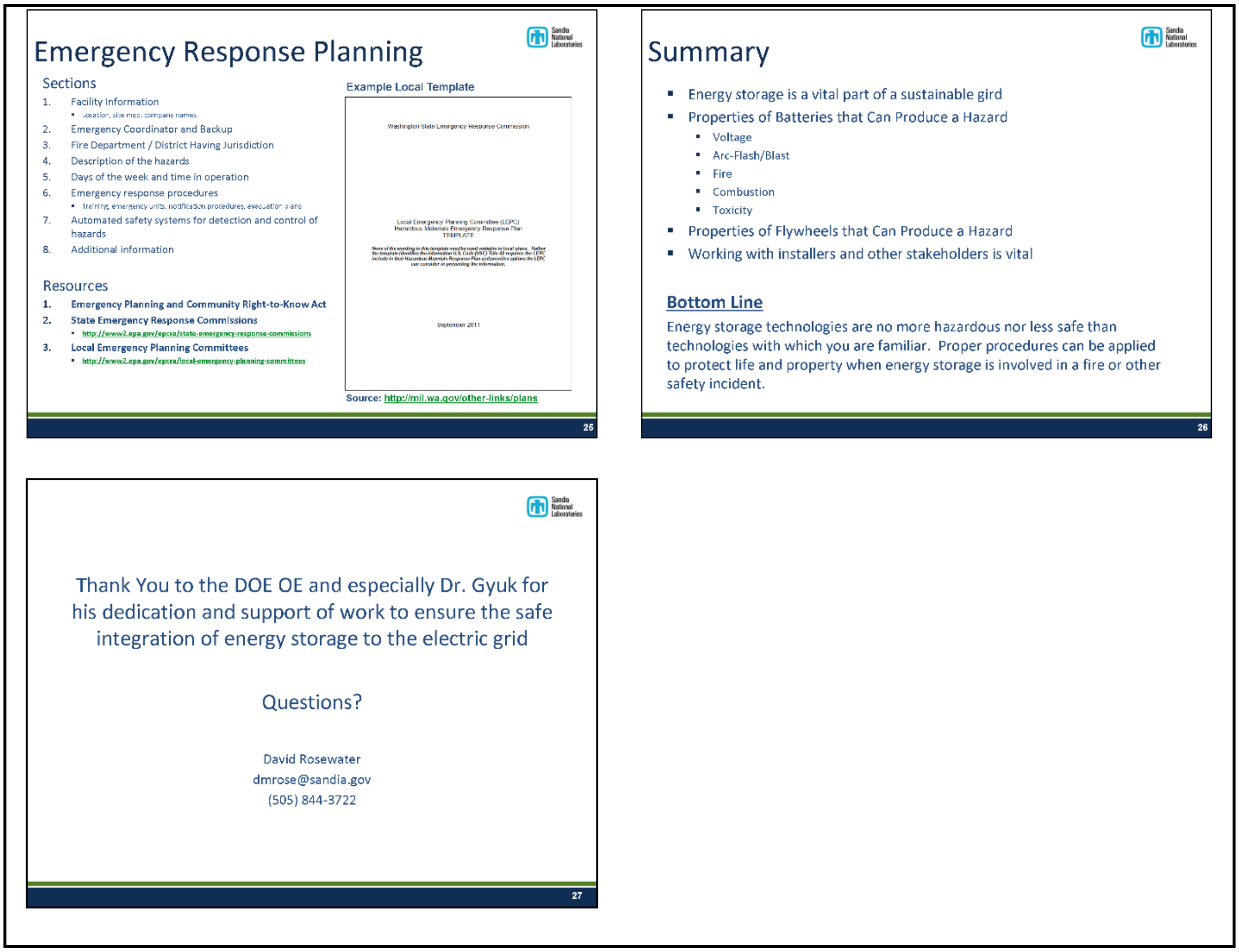

Figure 12: Presentation by David Rosewater (5 of 5)

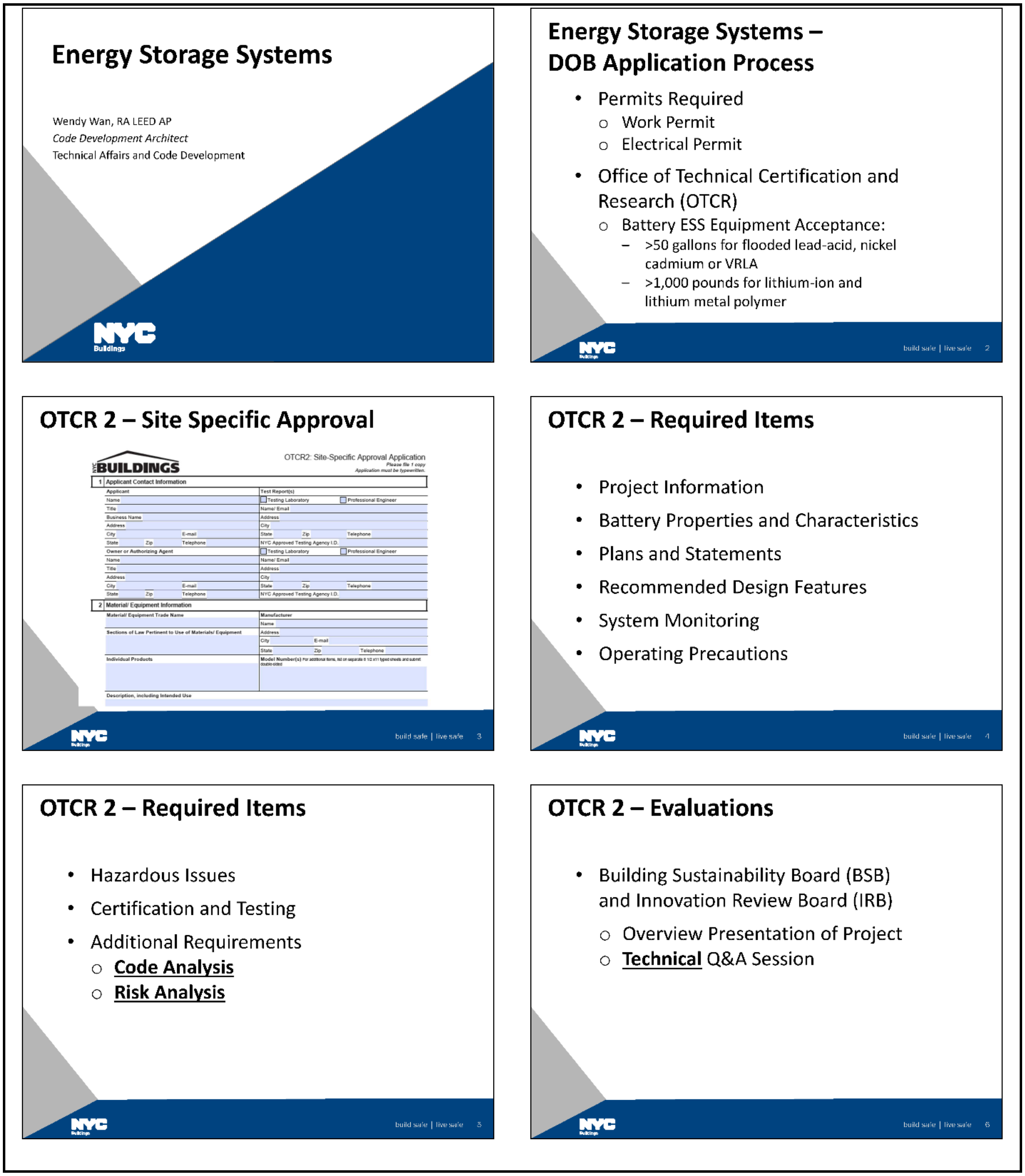

Figure 13: Presentation by Wendy Wan (1 of 2)

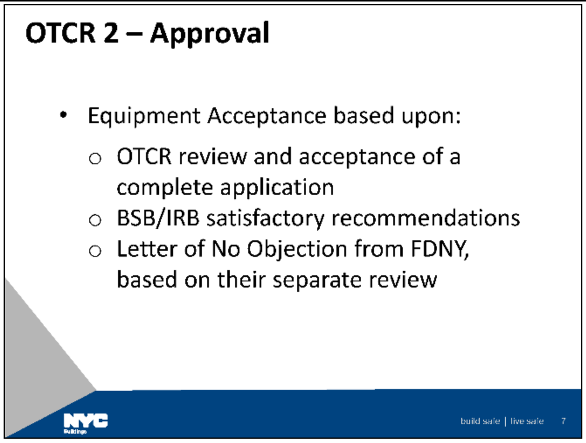

Figure 14: Presentation by Wendy Wan (2 of 2)

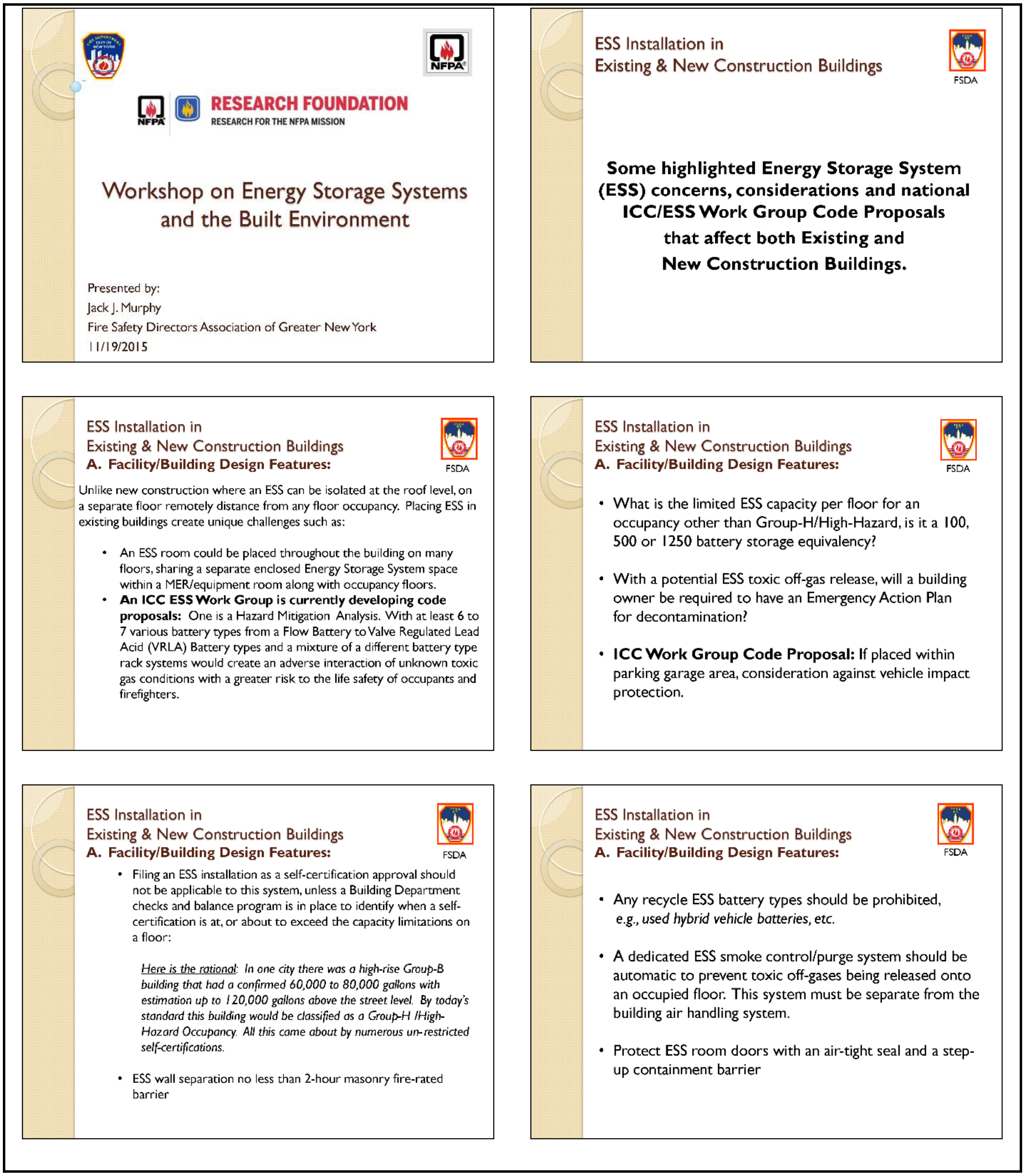

Figure 15: Presentation by Jack Murphy (1/2)

Figure 16: Presentation by Jack Murphy (2/2)

Figure 17: Presentation by Andrew Blum (1/3)

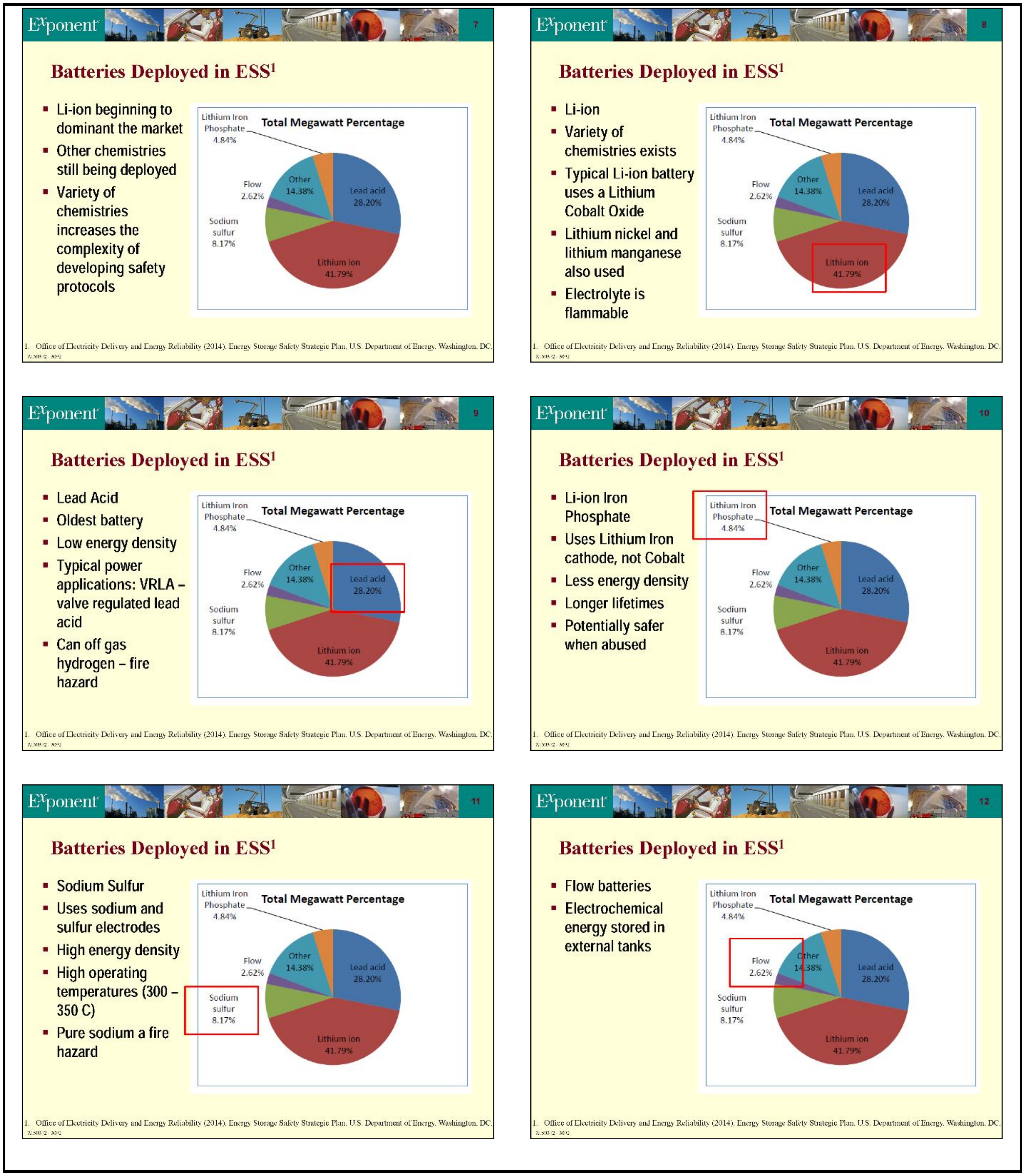

Figure 18: Presentation by Andrew Blum (2/3)

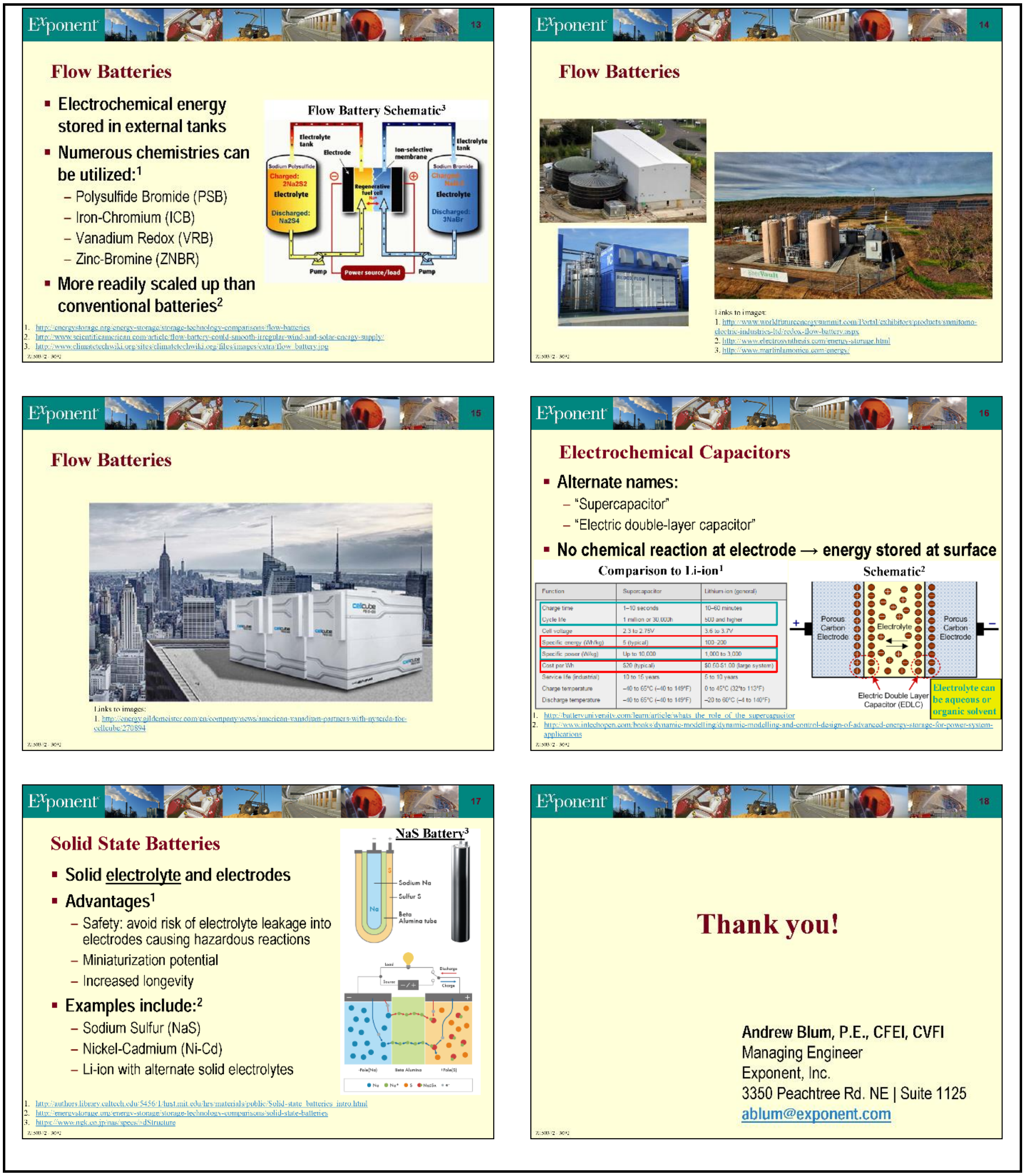

Figure 19: Presentation by Andrew Blum (3/3)

Figure 20: Presentation by Roger Lin (1/3)

Figure 21: Presentation by Roger Lin (2/3)

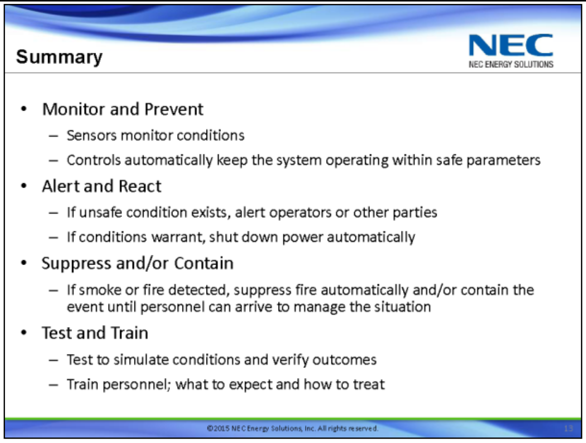

Figure 22: Presentation by Roger Lin (3/3)

NYSERDA/Con Edison Battery Safety Testing Initiative

NFPA/FDNY **Workshop on Energy Storage Systems and the Built Environment**

November 19, 2015

Con Edison: Jin Jin Huang, Amaury De La Cruz, Anthony Natale, and Britt Reichborn-Kjennerud

NYSERDA: Jason Doling

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Challenge We Are Addressing

- Con Edison peak demand reduction programs require innovative customer and utility sided solutions including energy storage (more later from Amaury De La Cruz…)
- Current NYC building and fire codes include the use of energy storage to Uninterruptable Power Supply (UPS) applications
  - Approval process for utility and customer sited peak demand applications and new technologies adds to project development schedule and cost
- Battery safety hazard assessment and first responders' guidelines are needed
  - Gaps exist in the testing literature and standards are evolving
- Con Edison/NYSERDA have developed a battery testing program to address key safety gaps
  - Activities developed in collaboration with FDNY and NYC DOB
  - Program designed to address near term needs in the absence of updated codes and standards, with general applicability

2

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Collaboration History and Project Team

- Nov 2014: FDNY/Con Edison collaboration formalized and project scoping
- Feb 2015: Project activities initiated
  - Current leakage test
  - Lead Acid Battery Burn
- Mar 2015: FDNY/NYC DOB/Con Edison/NYSERDA collaboration team formed
- August 2015: RFP for testing and computer modeling released
  - Scope of work developed specifically to address FDNY and NYC Department of Buildings needs
- Currently: Finalizing procurement phase for safety testing services

3

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February 2015 Current Leakage Test Results

- Testing conducted at The Rock
- Measured current leakage from 2 kV target to hose nozzle through the suppressant
  - Similar to UL 711 - Rating and Fire Testing of Fire Extinguishers (for Class C extinguishers)
- Suppression agents tested:
  - Water
  - Fire Ice
  - F-500
  - Universal Gold
- Results
  - An acceptable current threshold of 1 mA (NIOSH level of perception for the human body) was chosen
  - A safe operating distance of 10 ft with additional factors of safety was established for water, Fire Ice, and F-500

4

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Battery Testing Project Scope of Work - Overview

- Chemistries to undergo current testing program
  - Lead Acid
  - Lithium - Manganese Oxide
  - Lithium - Nickel Manganese Cobalt Oxide
  - Lithium - Titanate
  - Lithium - Iron Phosphate
  - Vanadium Redox Flow
- Cell level testing will be performed by an ISO 17025 certified lab
- Manufacturers will donate batteries for testing
- Chemistries and manufacturers chosen to address existing projects in Con Edison incentive program and NYC DOB queues
- Final report for public dissemination will include findings from the literature review, testing and computer modeling

5

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Battery Testing Project Scope of Work – Project Activities

- Literature Review
  - Include all chemistries being tested as well as sodium sulfur and nickel sodium chloride
  - Summarize the findings from previous battery safety testing
  - Include standard recommended ventilation during normal operations to address off gassing and fire mitigation strategies and suppression agents documented to be effective
  - Identify heat release and hazardous substances released during a thermal event

6

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Figure 23: Presentation by Britt Reichborn-Kjennerud (1/2)

Battery Testing Project Scope of Work – Project Activities

- Small Scale Cell Level Testing
  - Measure heat release rate
  - Measure species and rate of release of gasses liberated during a burn and as a result of application of suppression agents
  - Measure species and volume of liquids or solids released during a burn and as a result of application of suppression agents
  - Perform limited suppression agent testing of a small number of suppressants readily available to the FDNY: Water, F-500, FireIce®. Testing of suppression release rates for water, or if water is deemed ineffective or unsafe the next best candidate suppressant identified, will also be performed.
  - Observe for presence of electrical arcing or mini-explosions.

7

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Battery Testing Project Scope of Work – Project Activities

- Computer Modeling to System Scale
  - Used to extrapolate small scale burn test results to larger scale fire scenarios involving battery racks.
  - A model at the system scale will be constructed for each of the chemistries tested.
  - Model predictions will be validated through comparison with burn testing of intermediate units or strings of cells.
- We are in discussions with National Labs to complete additional system scale modeling using testing data from this program

8

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Battery Testing Project Scope of Work – Project Status and Timeline

- Plan for literature review and testing to commence at the end of 2015
- Final report anticipated by Q2 2016
- Early 2016: Identify additional stages of work including possible additional testing

9

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Figure 24: Presentation by Britt Reichborn-Kjennerud (1/2)

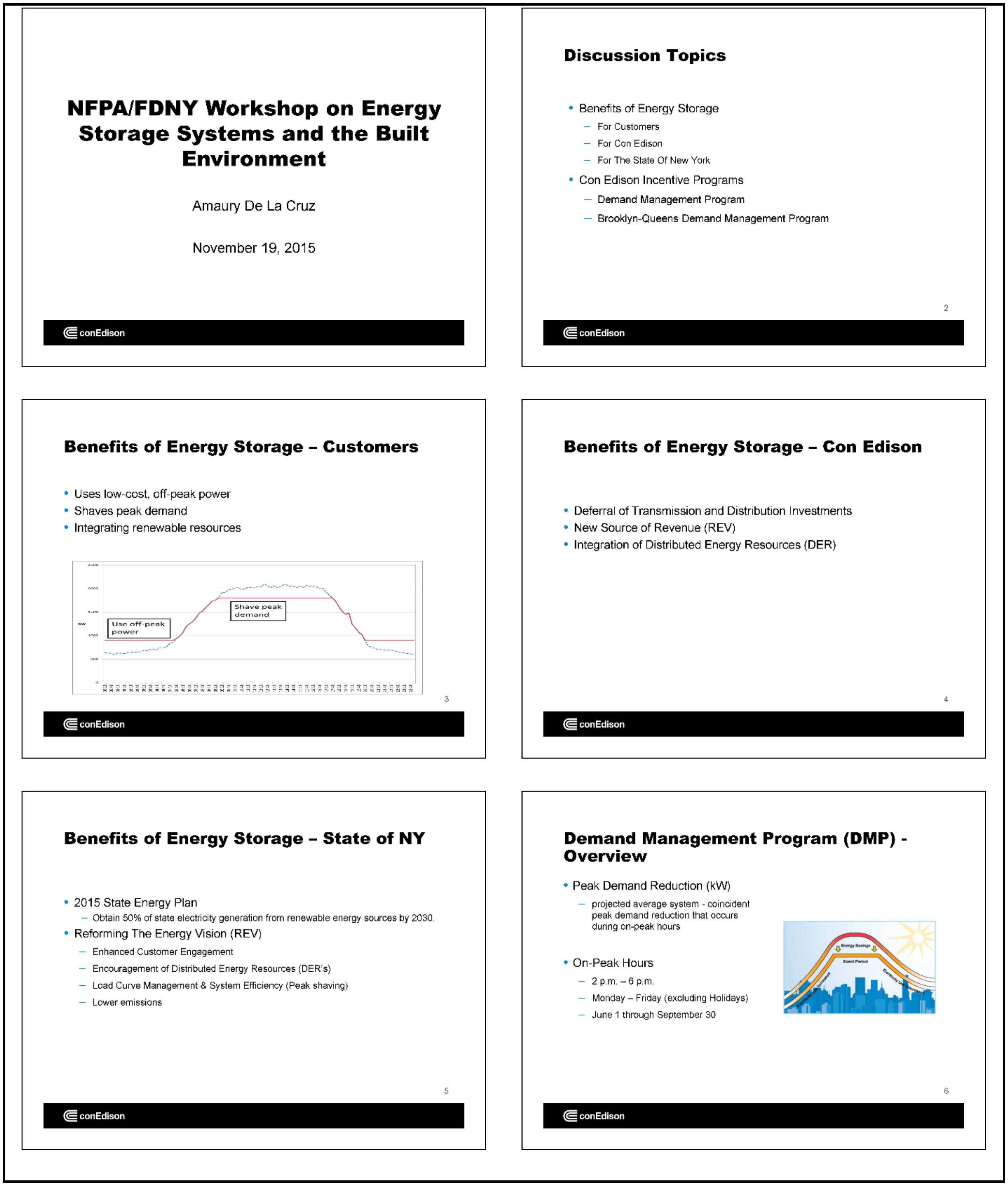

Figure 25: Presentation by Amaury De La Cruz (1/2)

Demand Management Program - Incentives

Project	Current Incentive	DMP Incentive/kW	Total Customer Benefit
Thermal Storage	$600/kW	$2,000	$2,600/kW
Battery Storage	$600/kW	$1,500	$2,100/kW
Chiller/HVAC/Controls/ Process Efficiency	$0.16/kWh	$1,250	$0.16/kWh + $1,250/kW
Lighting/LED	$0.16/kWh	$800	$0.16/kWh + $800/kW
DR Enablement	$200/kW	$600	$800/kW
Fuel Switching (Non-electric AC)	Steam AC Program		$500-$1,000/kW
Large Project Bonus			
Projects over 500 kW		+10% of kW incentive	Bonus funds are first installed, first paid.
Projects over 1MW		+15% of kW incentive	

7

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Demand Management Program - Projects

- 21 Battery Storage Project Applications Committed through the program
  - Capacity of 18 MW
  - 2 different battery chemistry families
    - Lithium Ion (multiple species)
    - Lead Acid
  - 4 of these projects are for indoor installations
  - 17 projects are outdoor installations
  - An additional 5 projects are prospecting, representing 7 MW of capacity.

8

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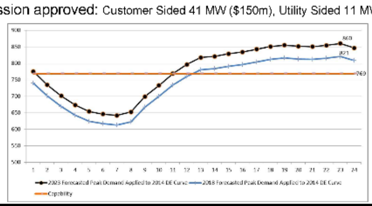
Brooklyn Queens Demand Management (BQDM) Program – Overview

- Sub-transmission feeders serving two networks in Brooklyn and one network in Queens overloaded (>800MW)
- Targeted peak period: 12pm-12am
- Commission approved: Customer Sided 41 MW ($150m), Utility Sided 11 MW ($50m)



9

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Brooklyn Queens Demand Management Program – Projects

- 18 Customer-sided proposals include battery energy storage
  - 5 different battery chemistry families
    - Lithium Ion (multiple species)
    - Zinc flow
    - Lead Acid
    - Sodium Sulfur
    - Sodium Nickel
  - Indoor and outdoor installations
- Utility-sided solution:
  - 1 MW capacity in multiple shipping containers, sited outdoors

10

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Thank You!

Amaury De La Cruz

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212-460-3093

11

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Figure 26: Presentation by Amaury De La Cruz (2/2)