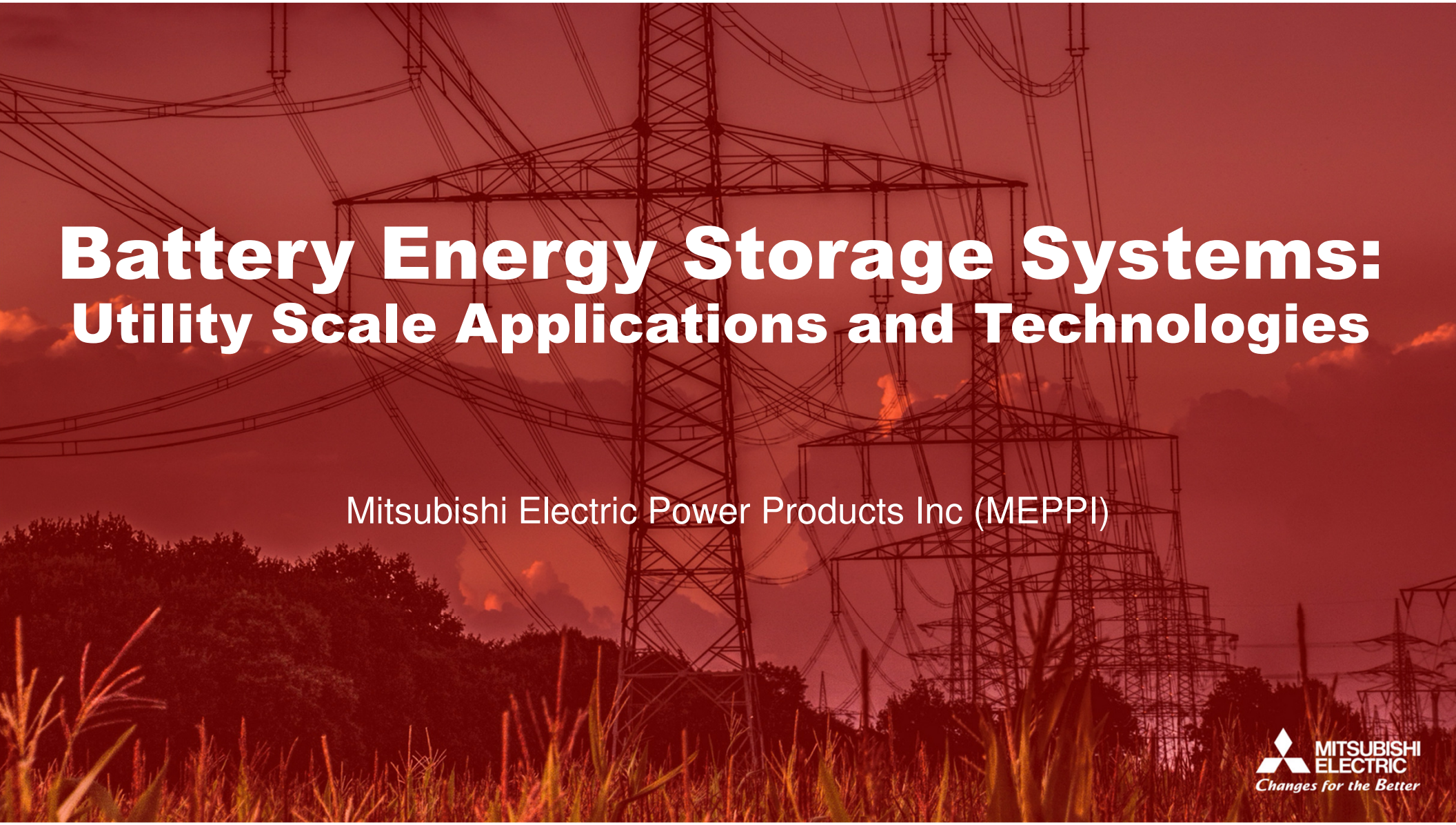


Battery Energy Storage Systems:
Utility Scale Applications and Technologies

Mitsubishi Electric Power Products Inc (MEPPI)

MITSUBISHI ELECTRIC
Changes for the Better

Utility Scale BESS Use Cases

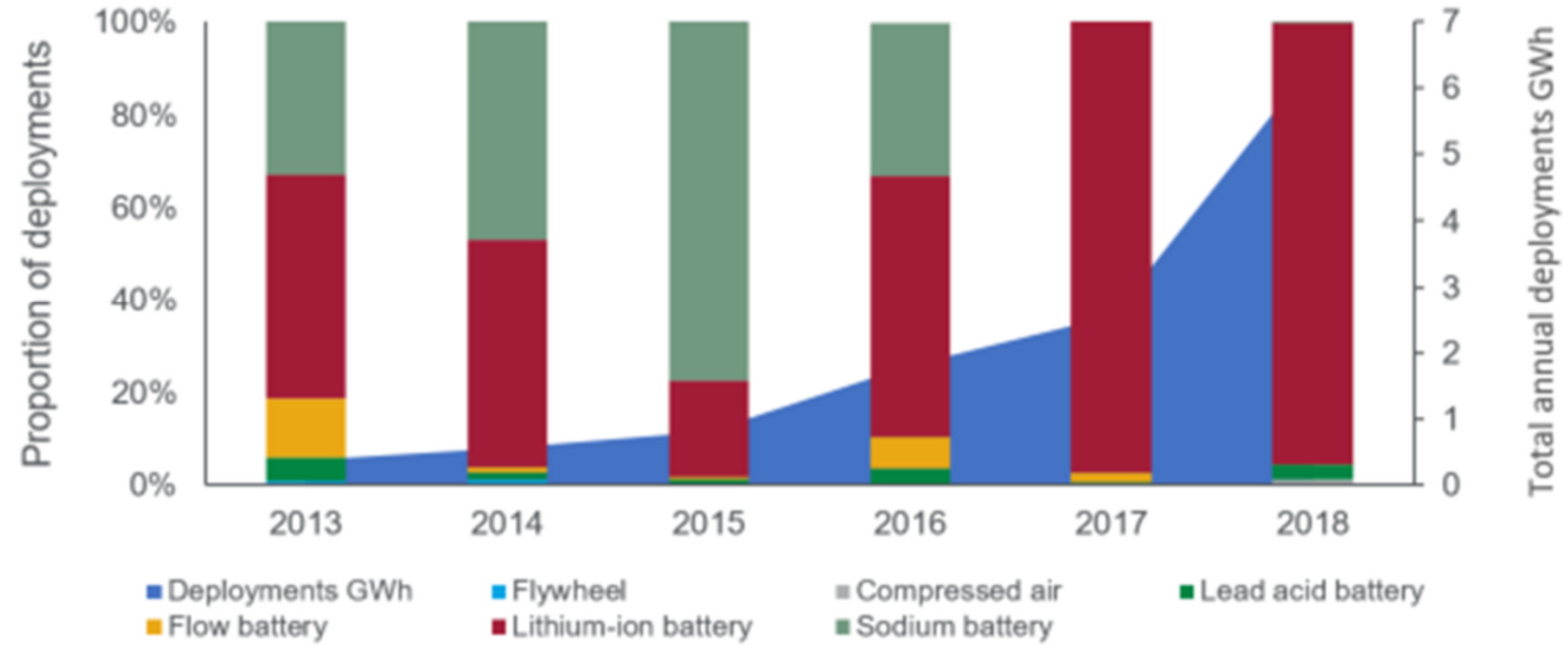
		Use Case Description
In-Front-of-the-Meter	1 Wholesale	• Large-scale energy storage system designed for rapid start and precise following of dispatch signal. Variations in system discharge duration are designed to meet varying system needs (i.e., short-duration frequency regulation, longer-duration energy arbitrage[1] or capacity, etc.) – To better reflect current market trends, this report analyzes one-, two- and four-hour durations[2]
	2 Transmission and Distribution	• Energy storage system designed to defer or avoid transmission and/or distribution upgrades, typically placed at substations or distribution feeders controlled by utilities to provide flexible capacity while also maintaining grid stability
	3 Wholesale (PV+Storage)	• Energy storage system designed to be paired with large solar PV facilities to better align timing of PV generation with system demand, reduce solar curtailment and provide grid support

Source: Lazard's LCOS Analysis – Version 6.0

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

Storage Technology Deployed

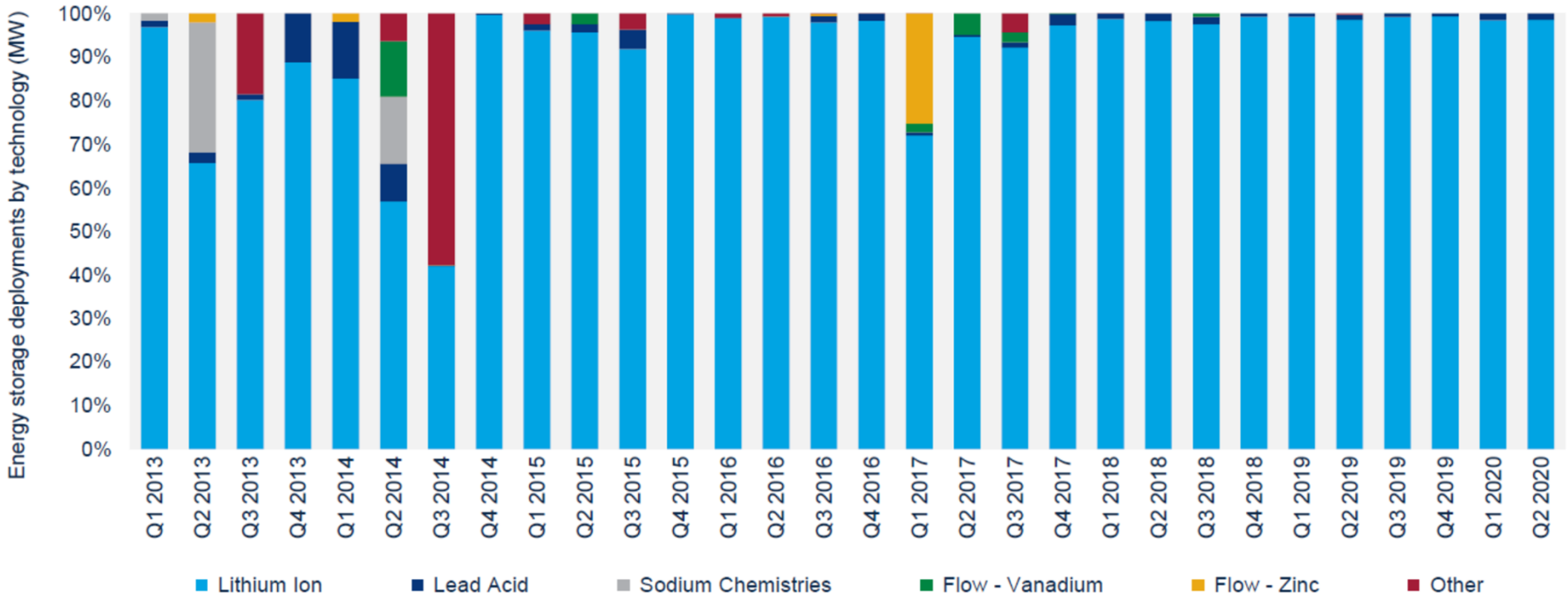


Source: Wood Mackenzie 2019.11.26 Post

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

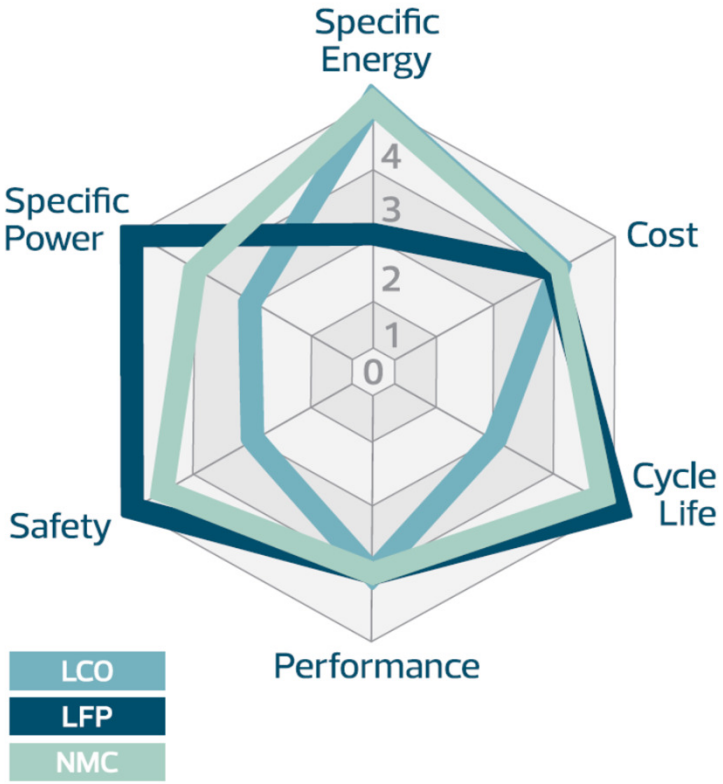
Battery Technology – Lithium Ion



PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

Battery Chemistries



Ref: InCell Academy

MITSUBISHI ELECTRIC

LCO (Lithium Cobalt Oxide)	**LFP (Lithium Iron Phosphate)**	NMC (Lithium Nickel Manganese Cobalt)
Moderate Safety	✓ Excellent Safety	Moderate Safety
Moderate Cycle life	✓ Excellent Cycle life	Excellent Cycle life
Good Power	✓ Excellent Power	Good Power
Good Cost	✓ Good Cost	Good Cost
Excellent Energy	✓ Moderate Energy	Excellent Energy

Safest Chemistry uses chemically stable LFP which does not exhibit the energetic thermal runaway that metal oxide lithium ion cells experience

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

Buildings, Containers, and Cabinets

MITSUBISHI ELECTRIC
Changes for the Better

Racks, Strings and Banks

CELL: 2.5-4.0V

MODULE: 40-100V

RACK/STRING: 600-1500V

Rack: Mechanical Integration of Cells and Modules
String: Electrical Integration of Cells and Modules
Bank/Array: DC bus containing multiple strings in parallel

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

Typical System – 20’ Container

CELL

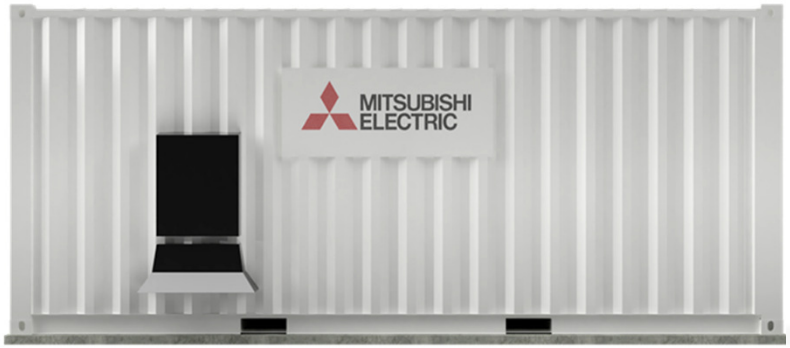
MODULE

RACK

CONTAINER

Key Features

- Typical Layout
- ~ 10 racks per 20ft container
- Multiple lift points either side
- DC collection boxes
- DC / AC Cables for stacks
- HVAC units
- Lighting and receptacles
- AC Panel
- Fire Suppression system



(Exterior)

(Interior)

MITSUBISHI ELECTRIC
Changes for the Better

Typical System – 40’ Container

CELL

MODULE

RACK

CONTAINER

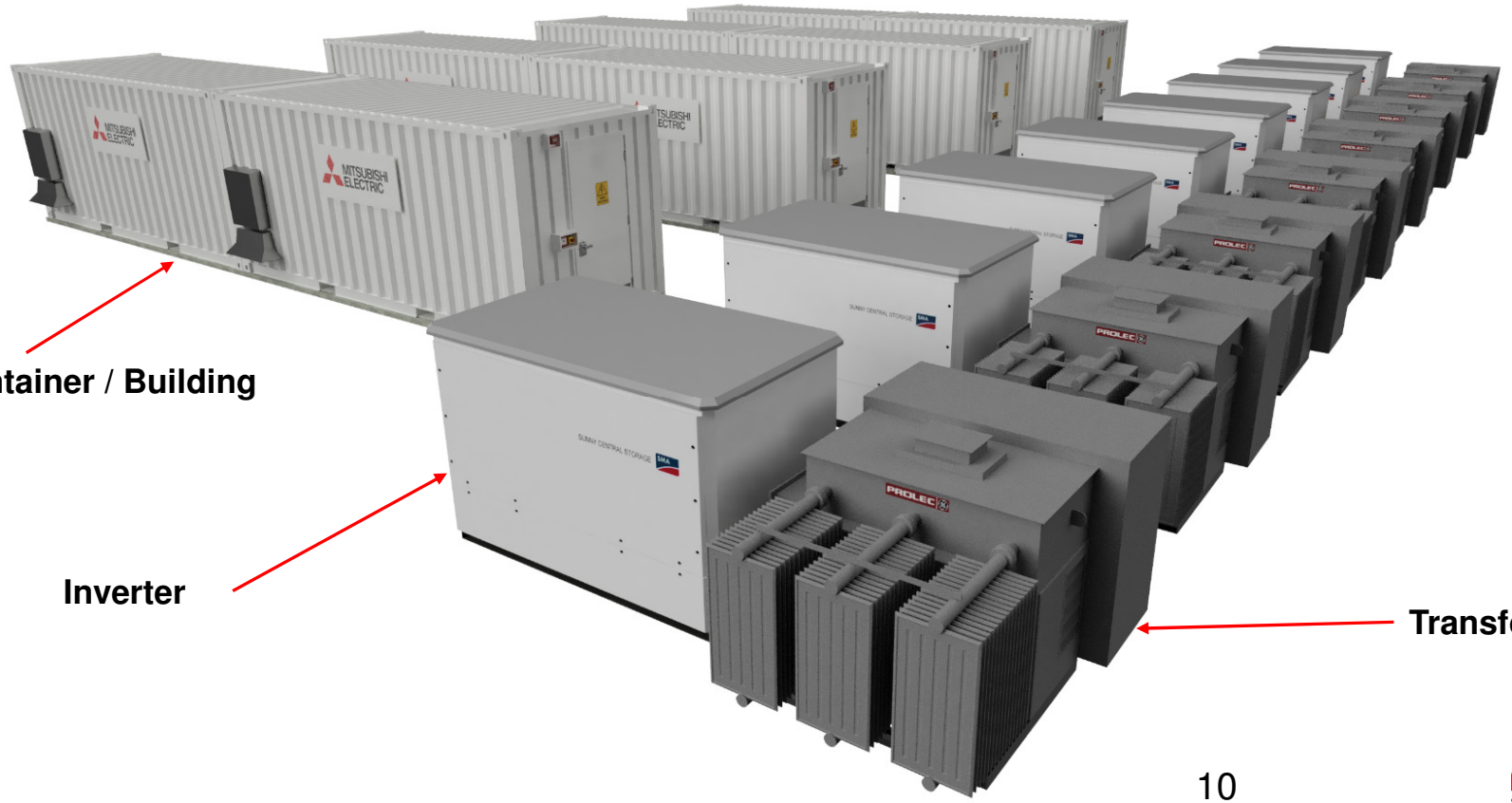
(Exterior) (Interior)

Key Features

- Typical Layout
- ~ 20 racks per 40ft container
- External access to stacks
- Multiple lift points either side
- DC collection boxes
- DC / AC Cables for stacks
- HVAC units
- Lighting and receptacles
- AC Panel
- Fire Suppression system

MITSUBISHI ELECTRIC
Changes for the Better

Typical System Layout

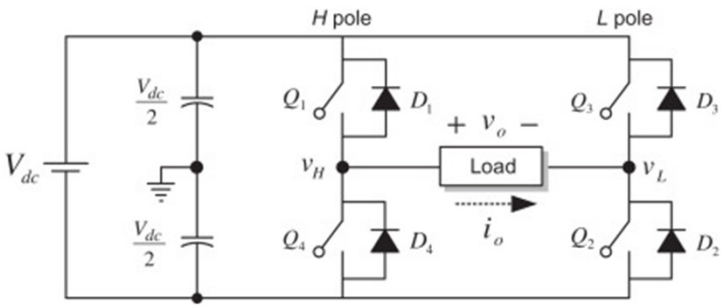


MITSUBISHI ELECTRIC
Changes for the Better

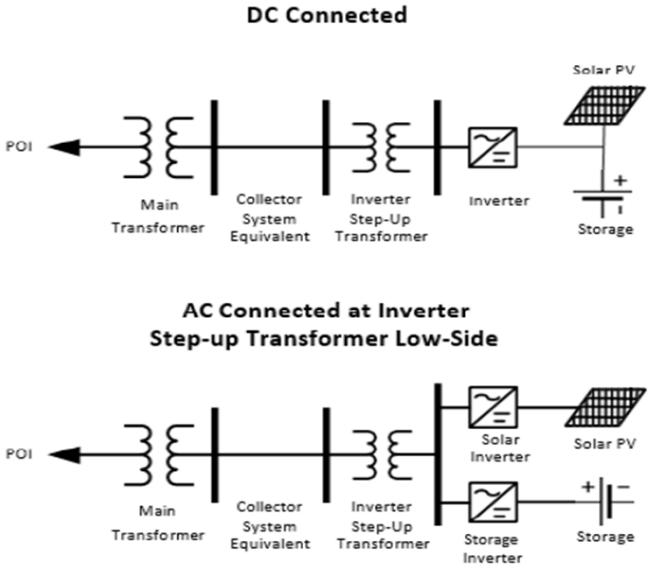
Grid Integration

DC Collection

AC/DC Conversion



AC Collection

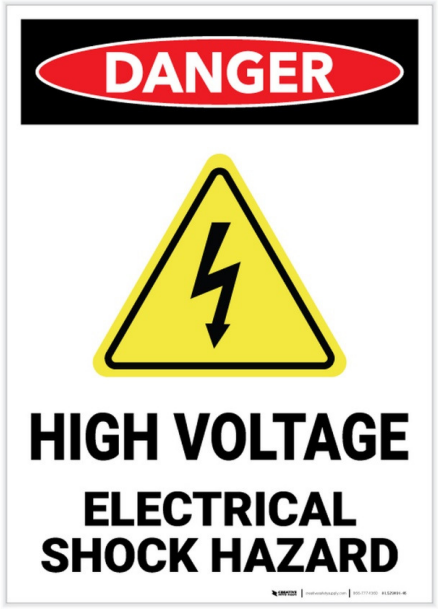


Source: Georgia Transmission, Sang-Hoon Kim, in Electric Motor Control

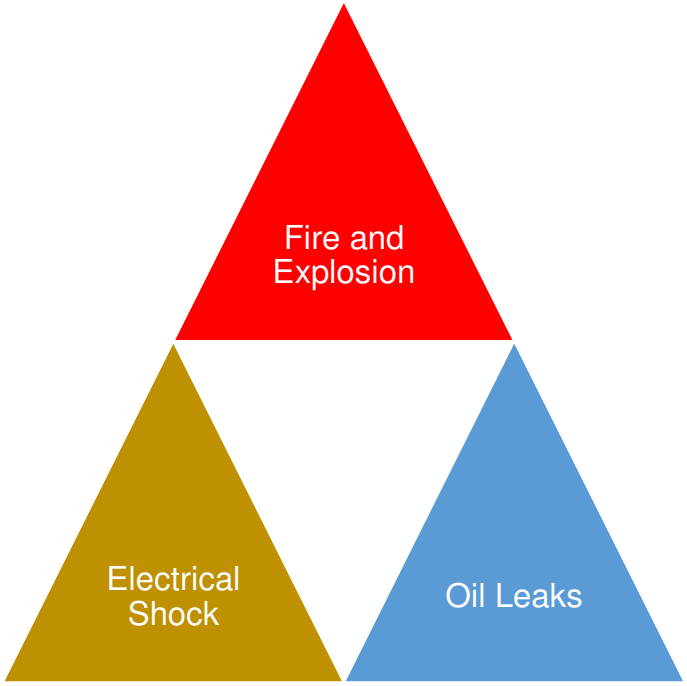
PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

Lithium-Ion BESS Hazards



UL9540a
NFPA 855



PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

Battery Safety Standards

UL9540 – Standard for Energy Storage Systems and Equipment. Updated in 2020.

UL9540a – Test Method for Evaluating Thermal Runaway Fire Propagation for UL9540 systems and components. Updated in 2019.

UL1973 – Standard for Batteries for use in stationary, vehicle, auxiliary power and light electrical rail applications. Focus on components. Updated in 2018.

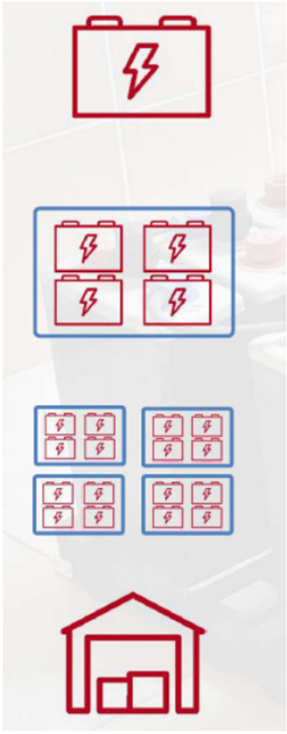
NFPA855 – Standard for the Installation of Stationary Energy Storage System which provides minimum requirements for mitigating the relevant hazards. Updated in 2020.

PROPRIETARY AND CONFIDENTIAL

UL9540a Test Method

UL9540a tests UL9540 systems and referenced by NFPA855.

Level	Activities
Cell	Develop cell thermal runaway initiation technique and characteristics including gas composition
Module	Determine propagation behavior within module and thermal energy release outside of the module.
Unit	Open test configuration of unit to unit fire spread with heat release rate and gas analysis to determine potential for explosion
Installation	Closed room test configuration of unit to unit fire spread with fire mitigation equipment

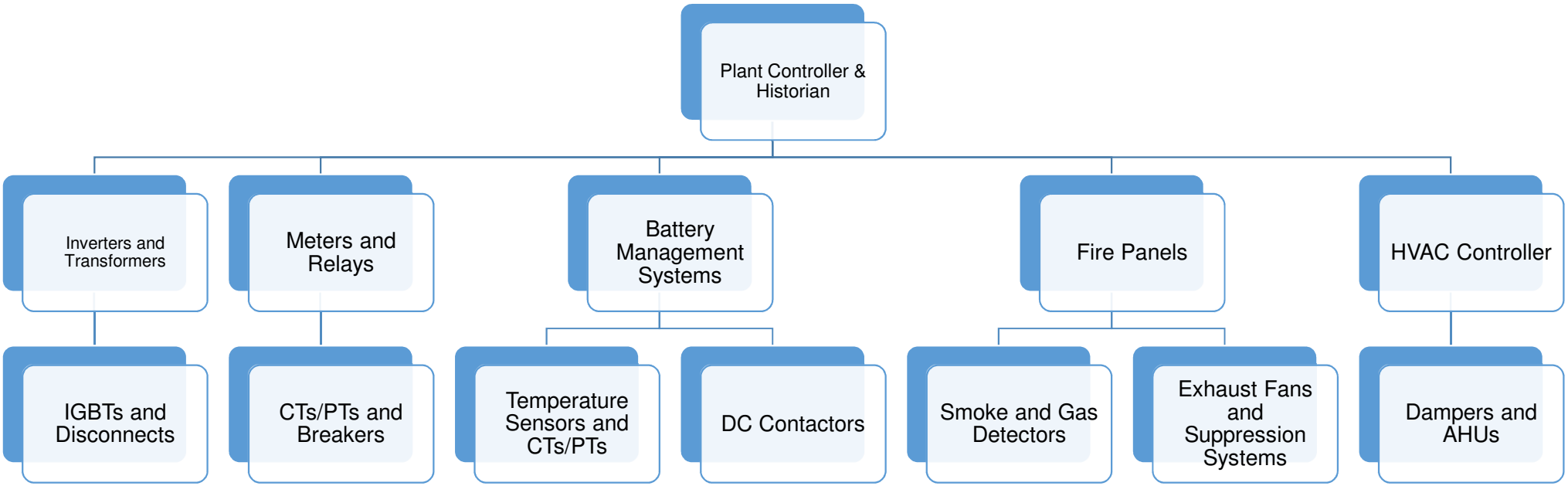


Source: UL 9540A Test Method Brings Clarity to Industry and Code Authorities

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

Controls and Monitoring



PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

SCADA and ISO/RTO Integration

Communication Protocols

- Modbus
- DNP3
- OPC UA/DA

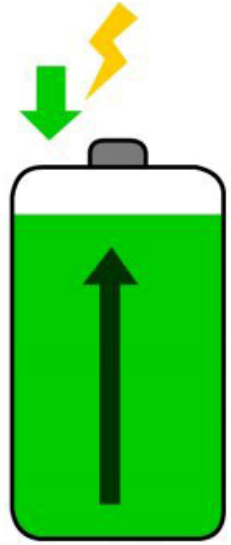
Points List Specifications

- MESA-DER DNP3 Map
- SunSpec/MESA-Device Modbus Map
- Customer Defined Interface

PROPRIETARY AND CONFIDENTIAL

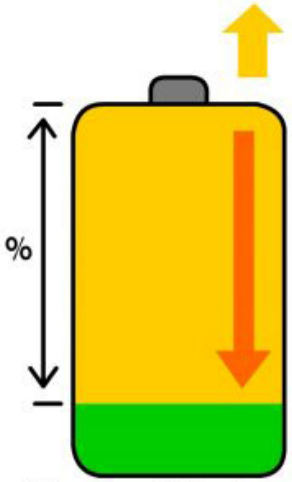
MITSUBISHI ELECTRIC
Changes for the Better

Round Trip Efficiency and Self Discharge



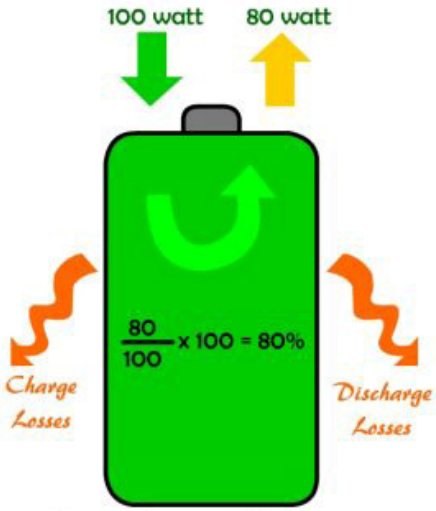
State of charge (SoC)

The current state of a battery.



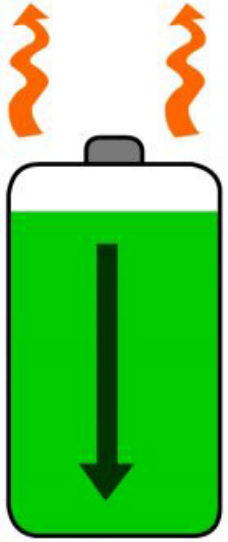
Depth of discharge (DoD)

The amount of a battery's capacity that has been used. Most manufacturers will specify a maximum DoD for optimal performance related to lifetime of the battery after repeated use.
A fully discharged battery will have shorter reusable lifespan.



Round-trip efficiency

The ratio of the energy recovered from the energy storage device and the energy input into the device.
Losses includes heat loss.



Self Discharge Rate

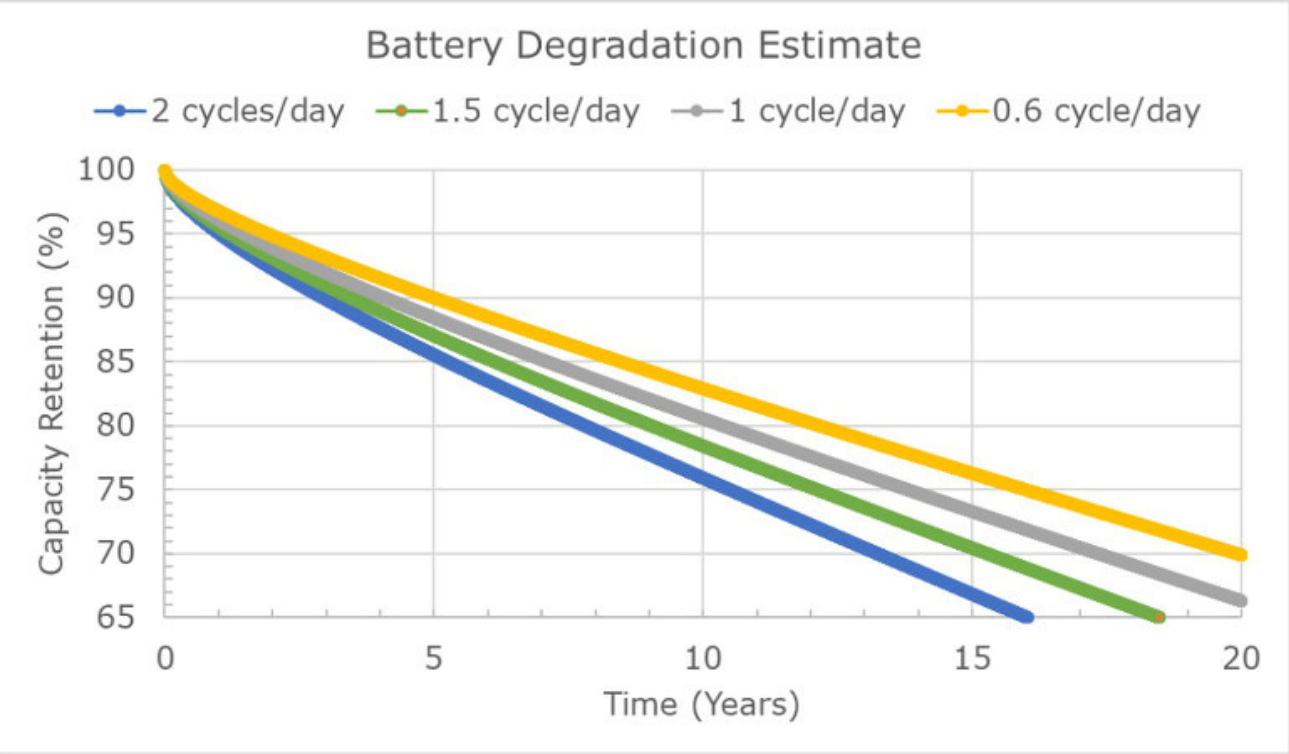
Self-discharge decreases the shelf life of batteries and causes them to initially have less than a full charge when actually put to use.

PROPRIETARY AND CONFIDENTIAL

Source: Future Green Technology

MITSUBISHI ELECTRIC
Changes for the Better

Capacity Retention and Degradation



A cycle here is defined as a kWh discharged per kWh installed.

For example, a 10 kWh battery operating at 2 cycles per day would discharge 20 kWh each day. Useful life varies significantly by cell type.

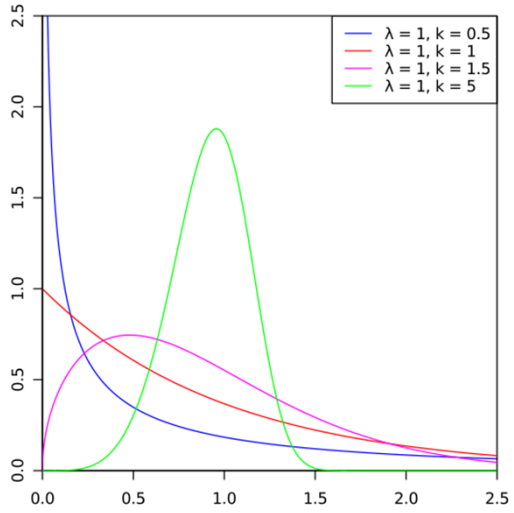
Source: DNV GL

PROPRIETARY AND CONFIDENTIAL

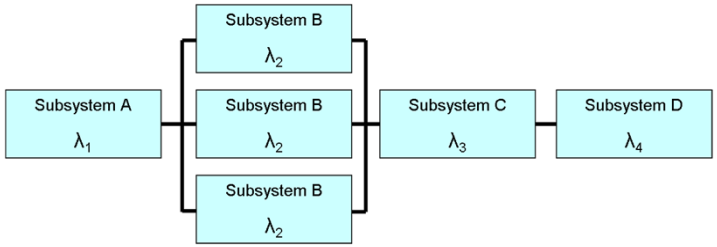
MITSUBISHI ELECTRIC
Changes for the Better

Availability and Reliability

Failure Rate



Operational Redundancy



Time to Repair

PROPRIETARY AND CONFIDENTIAL

Source: Wikipedia

MITSUBISHI ELECTRIC
Changes for the Better

Energy Storage – System Design

What basic information does MEPPI need to quote a system?

- Application
- Location
- Power (MW)
- Energy (MWh) or Duration (hours)
- Are these ratings at beginning or end of life?
- How often is the system being used?
- What is the life expectancy of the system?

Please note that each answer impacts design, equipment selection, and cost!

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better

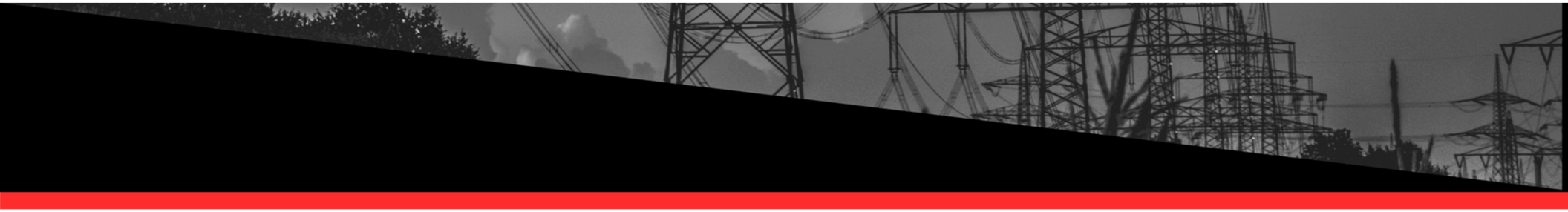
Final Thoughts

- Lithium-ion will remain dominant in near term
- Safety starts with the battery cell [LFP is preferred]
- NFPA-855 is under active development and review
- DC protection is still evolving from PV to batteries
- Augmentation strategies not usually guaranteed
- Need to be confident turnkey solution provider can deliver

How can MEPPI help you?

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better



Thank You!
Questions?

brendan.mcnicholas@meppi.com

adam.kabulski@meppi.com

PROPRIETARY AND CONFIDENTIAL

MITSUBISHI ELECTRIC
Changes for the Better