Supercapacitor Applications On The Scale Of Economics

Supercapacitor vs. Other Energy Storage Options By TCO

International Workshop Of Supercapacitors And Energy Storage
28Jun2019 - Bologna, Italy

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Powering Business Worldwide

Agenda

1. Eaton As Energy Storage Provider
2. Eaton As Supercapacitor Solution Provider
3. Supercapacitors vs. Other High Power Energy Storage Alternatives
4. Supercapacitors Energy Storage Applications On An Economical Scale

What matters to our customers, matters to us

Panama Canal
Energizing the Panama Canal to take on double the traffic

Facebook
Energizing data center as forward-thinking as Facebook itself

Valero
Energizing a refinery to take arc flash danger out of the operation

Schaltanlagenbau Gormanns GmbH
Energizing a potato plant to make sorting 120 tons of potatoes a one-man job

Johann Cruijff ArenA
Energizing by stored energy saving 117.000 tons of CO2

TriRiver Health Partners
Energizing IT systems to power the transformation of healthcare

Beijing subway
Energizing a subway system to move even faster than the speed of a growing Beijing

PGE Salem Smart Power Center
Energizing a working smart grid for energy intelligence.

Eaton is a global power management company

Powering Business Worldwide

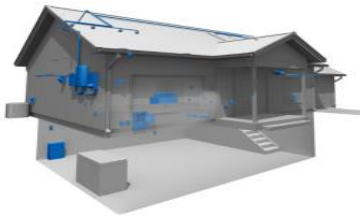
A partnership of environmental excellence

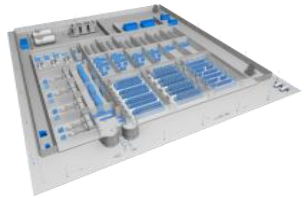
Powered by NISSAN MOTOR CORPORATION

EATON Powering Business Worldwide

By partnering with **Nissan** amongst others, we provide energy storage solutions in the full range of energy capacity.

RESIDENTIAL	COMMERCIAL	INDUSTRIAL





Expertise - Reach - Dependability - Diversity - Footprint - Portfolio

Eaton can partner with you to help you achieve substantial benefits.

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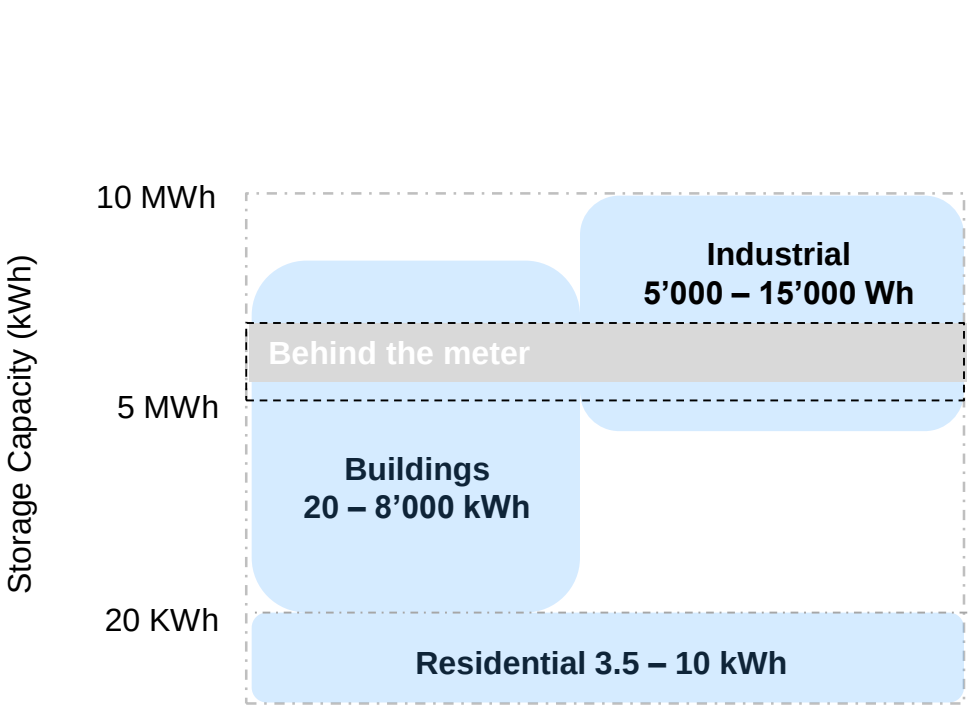
Scalable Solutions Utilizing The Appropriate Energy Storage Technologies



Amsterdam ArenA with xStorage Buildings **3MW** storage, Netherlands

Webaxys datacenter with xStorage Buildings **40kW** scalable storage Le Havre, France

Home energy storage unit xStorage Home available to utilities and homeowners

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Providing Supercapacitor Energy Storage For Critical Applications

- Superior Lifetime Cells
- High Power and Energy Density Laser Welded Module Structures

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Eaton's Supercap History

2.5V → **2.7V** → **3.0V**

A Series

B Series

HB Series

HBv2 Series

HV Series

X Series

XL60 Series

TV Series

XT Series

2 to 5 cell packs

1999 2000 2006 2008 2010 2012 2013 2014 2015 2016 2017 2018

Acquired PowerStor Supercaps

PowerStor

KR Series

KW Series

XVM Module

XLM Module

XLR Module

EATON
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Eaton's Supercap Cell Type Features

Eaton Cell Series	B/HB/PHV/XB	HV/PHV/XV/XL60 2.7	TV/XT/XL60 3.0
Product Picture			
Cell Voltage	2.5	2.7	3.0
Total Stored Energy (normalized)	1.0	1.2	1.4 (+23% TV vs. HV)
Typical usable energy*	1.0	1.3	1.8 (+38% TV vs. HV)
Peak Power** (normalized)	1.0	1.8	2.2 (+23% TV vs. HV)
Application Benefit	• Non Toxic • Non Flammable • Good high temp life performance	• Widest selection (1-3400F) • Industry's lowest ESR • Good low temp performance up to -40C	• Industry's highest power desity • Industry's leading lifetime (approx 2x vs. HV) • Industry's highest stored energy

*Vcutoff=1.3V and Vcharge at 0.3V less than Vrated
**varies by size due to ESR differences

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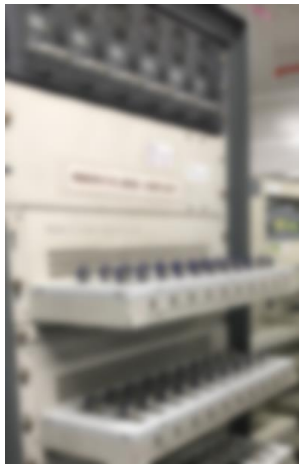
PowerStor Technology - Manufacturing

Coating Machine

Winding Machine

- ✓ Improved electrode quality as a result of state-of-art coating & calendaring machines providing improved product performance
- ✓ Adding automated assembly and dry room has lead to improved quality & consistency
- ✓ Adding automated Cap, ESR and LC measurement for 100% of the products resulting excellent quality
- ✓ Excellent traceability by printing date/batch code on each supercaps (ex coincells)
- ✓IATF16949 qualified facility to comply with automotive requirements

Assembly Machines and Dry Room



Coincell Auto Test Unit

Cylindrical Cell Auto Aging & Testing Unit

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Eaton Supercap Portfolio – 2.5-3.0V Single Cells

OEM Automotive Qualified

Picture	Family	Capacitance (F)	Part Number	*** ESR (mohm)	Nominal Voltage (V)	Operating Temp	Size (mm)	* Leakage Current (uA)	** Applications	Notes
	B Series	0,22	B0508-2R5224-R	2000	2,5	-25C to +70C	5 x 11	2	Low Current Hold-up RTC & Memory Back-up Gas, Water, Electricity Meters	
		1	B0810-2R5105-R	500	2,5	-25C to +70C	8 x 13	4		
		1,5	B1010-2R5155-R	300	2,5	-25C to +70C	10 x 14	7		
		2,2	B1020-2R5225-R	200	2,5	-25C to +70C	8 x 20	9		
	HB Series	3	HB0820-2R5305-R	150	2,5	-25C to +70C	8 x 20	7	Gas, Water, Electricity Meters Pulse Power Hold-up Power RTC & Memory Back-up RAID Data Storage Emergency Lights	Linear voltage de-rating to +85C @ 2.1V
		5	HB1020-2R5505-R	95	2,5	-25C to +70C	10 x 20	11		
		6	HB0830-2R5605-R	95	2,5	-25C to +70C	8 x 30	11		
		10	HB1030-2R5106-R	60	2,5	-25C to +70C	10 x 30	20		
		15	HB1325-2R5156-R	45	2,5	-25C to +70C	13 x 26	22		
		25	HB1625-2R5256-R	36	2,5	-25C to +70C	16 x 25	28		
		35	HB1635-2R5356-R	28	2,5	-25C to +70C	16 x 35	32		
		60	HB1840-2R5606-R	23	2,5	-25C to +70C	18 x 40	47		
		110	HB1860-2R5117-R	18	2,5	-25C to +70C	18 x 60	180		
	HV Series	1	HV0810-2R7105-R	200	2,7	-40C to +65C	8 x 10	10	Gas, Water, Electricity Meters Pulse power Hold-up Power Asset Tracking Solid State Drives (SSD) GPS Telecom UPS Automotive Local Energy	Linear voltage de-rating to +85C @ 2.3V
		3	HV0820-2R7305-R	80	2,7	-40C to +65C	8 x 20	15		
		5	HV1020-2R7505-R	40	2,7	-40C to +65C	10 x 20	20		
		6	HV0830-2R7605-R	40	2,7	-40C to +65C	8 x 30	20		
		10	HV1030-2R7106-R	34	2,7	-40C to +65C	10 x 30	23		
		15	HV1325-2R7156-R	30	2,7	-40C to +65C	13 x 26	23		
		25	HV1625-2R7256-R	27	2,7	-40C to +65C	16 x 25	45		
		35	HV1635-2R7356-R	24	2,7	-40C to +65C	16 x 35	98		
		35	HV1245-2R7356-R	20	2,7	-40C to +65C	12 x 45	75		
		60	HV1840-2R7606-R	18	2,7	-40C to +65C	18 x 40	110		
		100	HV1860-2R7107-R	12	2,7	-40C to +65C	18 x 60	260		
	TV Series	5	TV1020-3R0505-R	35	3	-40C to +65C	10 x 20	13	Pulse Power Electricity Meters Telecom UPS Gambling Machine UPS Embedded/Industrial PC UPS	Linear voltage de-rating to +85C @ 2.5V
		10	TV1030-3R0106-R	26	3	-40C to +65C	10 x 30	25		
		15	TV1325-3R0156-R	24	3	-40C to +65C	13 x 25	35		
		25	TV1625-3R0256-R	18	3	-40C to +65C	16 x 25	60		
		34	TV1245-3R0346-R	16	3	-40C to +65C	12 x 45	75		
		35	TV1635-3R0356-R	15	3	-40C to +65C	16 x 35	90		
		60	TV1840-3R0606-R	13	3	-40C to +65C	18 x 40	135		
		100	TV1860-3R0107-R	11	3	-40C to +65C	18 x 60	225		
	XB Series	300	XB3550-2R5307-R	7,0	2,5	-25C to +70C	35 x 50	300	Pulse Power Telecom Hold-up/ UPS RAID Storage Mains Fail Protection	Linear voltage de-rating to +85C @ 2.1V
		400	XB3560-2R5407-R	4,5	2,5	-25C to +70C	35 x 60	400		
		600	XB3585-2R5607-R	3,7	2,5	-25C to +70C	35 x85	700		
	XV Series	300	XV3550-2R7307-R	4,5	2,7	-40C to +65C	35 x 50	480	X-Ray Power Telecom Hold-up/ UPS Pulse Power Emergency Lighting	Linear voltage de-rating to +85C @ 2.1V
		400	XV3560-2R7407-R	3,2	2,7	-40C to +65C	35 x 60	650		
		600	XV3585-2R7607-R	2,6	2,7	-40C to +65C	35 x 85	1300		
	XT Series	275	XT3560-3R0377-R	4,5	3	-40C to +65C	35 x 60	600	Pulse Power Telecom Hold-up/ UPS RAID Storage Mains Fail Protection	Linear voltage de-rating to +85C @ 2.6V
		370	XT3560-3R0377-R	3,2	3	-40C to +65C	35 x 60	850		
		555	XV3585-3R0557-R	2,6	3	-40C to +65C	35 x 85	1300		
	XL60 Series	3000	XL60-2R7308W-R	0,23	2,7	-40C to +65C	60 x 138	5000	Engine starting Energy capture and re-use Power Line Conditioning	Linear voltage de-rating to +85C @ 2.3V
		3000	XL60-2R7308T-R	0,23	2,7	-40C to +65C	60 x 138	5000		
		3400	XL60-2R9348W-R	0,23	2,85	-40C to +65C	60 x 138	8000		Linear voltage de-rating to +85C @ 2.45V
		3400	XL60-2R9348T-R	0,23	2,85	-40C to +65C	60 x 138	8000		
		3000	XL60-3R0308W-R	0,23	3	-40C to +65C	60 x 138	5000		Linear voltage de-rating to +85C @ 2.6V
		3000	XL60-3R0308T-R	0,23	3	-40C to +65C	60 x 138	5000		

* Leakage current measured after 72hr at full rated voltage and room temperature
** The listed applications are general, for specific applications please contact our local sales, FAE team
*** ESR is measured at 1kHz except for B, PB, KR and KW where ESR data is based on 100Hz measurement

Elektronik Produkte des Jahres 2017

Elektronik Produkte des Jahres 2014

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Eaton Supercap Portfolio – 5-5.5V Packs & Coincells

Picture	Family	Capacitance (F)	Part Number	*** ESR (ohm)	Nominal Voltage (V)	Operating Temp	Size (mm)	* Leakage Current (uA)	** Applications	Notes
	PB Series	0,1	PB-5R0V104-R	4,0	5	-25C to +70C	5.5 x 10.8 x 12.5	3	Gas, Water, Electricity Meters Low Current Hold-up RTC & Memory back-up	
		0,47	PB-5R0V474-R	1,0	5	-25C to +70C	8.5 x 16.8 x 14	7		
		1	PB-5R0V105-R	0,5	5	-25C to +70C	8.5 x 16.8 x 21.5	12		
	PHB Series	1,5	PHB-5R0V155-R	0,310	5	-25C to +70C	8.5 x 16.8 x 21.5	10	Gas, Water, Electricity Meters Pulse power Hold-up power RTC & Memory back-up	Linear voltage de-rating to +85C @ 4.0V
		2,5	PHB-5R0V255-R	0,190	5	-25C to +70C	10.5 x 20.8 x 22.5	14		
		3	PHB-5R0V305-R	0,190	5	-25C to +70C	8.5 x 16.8 x 31.5	16		
		5	PHB-5R0V505-R	0,120	5	-25C to +70C	10.5 x 20.8 x 32	25		
	PHV Series	0,47	PHV-5R4V474-R	0,300	5,4	-40C to +65C	8.5 x 16.8 x 14	13	Pulse Power Gas, Water, Electricity Meters Asset Tracking Remote Monitoring	Linear voltage de-rating to +85C @ 4.0V
		1,5	PHV-5R4V155-R	0,100	5,4	-40C to +65C	8.5 x 16.8 x 21.5	18		
		2,5	PHV-5R4V255-R	0,070	5,4	-40C to +65C	10.5 x 20.8 x 22.5	24		
		3	PHV-5R4V305-R	0,070	5,4	-40C to +65C	8.5 x 16.8 x 31.5	25		
		5	PHV-5R4V505-R	0,065	5,4	-40C to +65C	10.5 x 20.8 x 32	28		
	PM Series	0,47	PM-5R0V474-R	0,420	5	-40C to +60C	8.5 x 16.8 x 14	8	Pulse Power Gas, Water, Electricity Meters Asset Tracking Remote Monitoring	Linear voltage de-rating to +85C @ 3.9V
		1	PM-5R0V105-R	0,150	5	-40C to +60C	8.5 x 16.8 x 21.5	10		
		1,5	PM-5R0155-R	0,070	5	-40C to +60C	10.5 x 20.8 x 22.5	15		
		3	PM-5R0305-R	0,050	5	-40C to +60C	10.5 x 20.8 x 32	20		
	KR Series (C Type)	0,1	KR-5R5C104-R	75	5,5	-25C to +70C	13.5 x 7.5	0,6	RTC Memory back-up	Ultra-low Leakage Current
		0,22	KR-5R5C224-R	75	5,5	-25C to +70C	13.5 x 7.5	1,3		
		0,33	KR-5R5C334-R	50	5,5	-25C to +70C	13.5 x 7.5	2		
		0,47	KR-5R5C474-R	50	5,5	-25C to +70C	13.5 x 7.5	2,8		
		1	KR-5R5C105-R	30	5,5	-25C to +70C	21.5 x 7.5	6		
		1,5	KR-5R5C155-R	30	5,5	-25C to +70C	21.5 x 7.5	9		
	KR Series (V Type)	0,1	KR-5R5V104-R	75	5,5	-25C to +70C	11.5 x 12.5	0,6	RTC Memory back-up	Ultra-low Leakage Current
		0,22	KR-5R5V224-R	75	5,5	-25C to +70C	11.5 x 12.5	1,3		
		0,33	KR-5R5V334-R	50	5,5	-25C to +70C	11.5 x 12.5	2		
		0,47	KR-5R5V474-R	50	5,5	-25C to +70C	11.5 x 12.5	2,8		
		1	KR-5R5V105-R	30	5,5	-25C to +70C	19 x 19.5	6		
		1,5	KR-5R5V155-R	30	5,5	-25C to +70C	19 x 19.5	9		
	KR Series (H Type)	0,1	KR-5R5H104-R	75	5,5	-25C to +70C	11.5 x 5	0,6	RTC Memory back-up	Ultra-low Leakage Current
		0,22	KR-5R5H224-R	75	5,5	-25C to +70C	11.5 x 5	1,3		
		0,33	KR-5R5H334-R	50	5,5	-25C to +70C	11.5 x 5	2		
		0,47	KR-5R5H474-R	50	5,5	-25C to +70C	11.5 x 5	2,8		
		1	KR-5R5H105-R	30	5,5	-25C to +70C	19 x 6.5	6		
		1,5	KR-5R5H155-R	30	5,5	-25C to +70C	19 x 6.5	9		
	KW Series (C Type)	0,1	KW-5R5C104-R	50	5,5	-40C to +85C	13.5 x 8.3	0,6	RTC Memory back-up Programmable Logic Control (PLC)	Ultra-low Leakage Current
		0,22	KW-5R5C224-R	50	5,5	-40C to +85C	13.5 x 8.3	1,3		
		0,33	KW-5R5C334-R	50	5,5	-40C to +85C	13.5 x 8.3	2		
		0,68	KW-5R5C684-R	30	5,5	-40C to +85C	21.5 x 9.0	2,8		
		1	KW-5R5C105-R	30	5,5	-40C to +85C	21.5 x 9.0	6		

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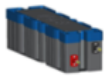
Eaton Supercap Porfolio – 16-69V Modules

UL recognized

CE & UL certified

UL recognized & UN ECE R100 qualified

Picture	Family	Capacitance (F)	Part Number	*** ESR (mohm)	Nominal Voltage (V)	Operating Temp	Size (mm)	* Leakage Current (aA)	** Applications	Notes
	XVM Module	65	XVM-16R2656-R	22	16.2	-40C to +65C	236x46x78	23	Emergency back-up Battery assist while cranking Equipment graceful shutdown	Compact Size Easy Mounting Maintanace Free
	XVM Board	4.2	XVM- 259R2425-R	310	259.2	-40C to +65C	550x266x94	27	UPS up to 50kW Medical Imaging Booster	Standard Rack Size Fit Fuse Included
		6.3	XVM- 259R2635-R	250	259.2	-40C to +65C	550x266x94	27	UPS up to 50kW Medical Imaging Booster	Standard Rack Size Fit Fuse Included
	XLM Series	130	XLM-62R1137A-R	6.7	62.1	-40C to +65C	686x176x173	128	UPS energy storage Kilo/Megawatt energy storage	Lowest ESR Longest Lifetime Maintanance Free
		130	XLM-69R0137A-R	6.7	69	-40C to +65C	686x176x173	128	UPS energy storage Kilo/Megawatt energy storage	Lowest ESR Longest Lifetime Maintanance Free
	XLR Series	667	XLR-24R3667-R	2.5	24.2	-40C to +65C	420x195x176	10.4	Energy Regeneration & Power Boost for Engine Start Material Handling	Lowest ESR Ruggedized Construction IP65
		166	XLR- 48R2167-R	5	48.6	-40C to +65C	420x195x176	5.2	Energy Regeneration & Power Boost for Transportation& Material Handling	Lowest ESR Ruggedized Construction IP65
		188	XLR- 51R3197-R	5.5	48.6	-40C to +65C	420x195x176	5.2	Energy Regeneration & Power Boost for Transportation& Material Handling	Lowest ESR Ruggedized Construction IP65

* Leakage current measured after 72hr at full rated voltage and room temperature

** The listed applications are general, for specific applications please contact our local sales, FAE team

*** ESR is measured at 1kHz except for B, PB, KR and KW where ESR data is based on 100Hz measurement

Eaton Supercap Cabinets

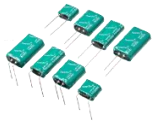
50kW / 20s

100kW / 20s

300kW / 10s

Powering Business Worldwide

Market / Application Matrix

Products	Computing	Transport	Industrial	Energy	Consumer	Medical
Coin Cells 	• Real time clock backup		• Real time clock backup	• RTC • Meter Anti-Tamper	• RTC • Low current holdup	• Real time clock backup
Cylindrical Cells 	• RAID Brown-out protection • SSD pulse power	• Emergency Call • Door Locks • Voltage sag protection • Asset tracking	• Brown-out protection • Pulse power • Emergency power/lights • Telecom UPS	• Smart meter pulse power • Smart meter backup power	• Gambling machine UPS • Toys power • Bicycle lights	• Pulse power for battery powered devices
Cylindrical Packs 	• RAID Brown-out protection • SSD pulse power	• E-Call units power • Asset tracking	• Embedded PC Brown-out protection • Machine Pulse power	• Smart gas&water meter pulse power	• Toys power • Bicycle lights • Billboards brownout protection	• Pulse power for battery powered devices
Large Cells 		• Energy regeneration – hybrids • Engine cold start/peak power	• UPS – PC/PLC level • Machine peak/pulse power • UPS – up to 50kW	• Solar Firming – residental size		• Mobile X-ray pulse power • Laser/aestethic surgery peak power
Modules 	• UPS – Datacenter facility	• Traction energy regeneration stationary/on-board • Electric trains – mains power bridge power	• UPS – facility • Peak shaving – machine level • Energy regeneration	• microGrid energy storage • Solar firming – solar field • High altitude wind energy regenerate		• Imaging peak shaving (CT, MR, Xray) • UPS – Hospitals

Supercapacitors vs. Other **High Power** Energy Storage Alternatives

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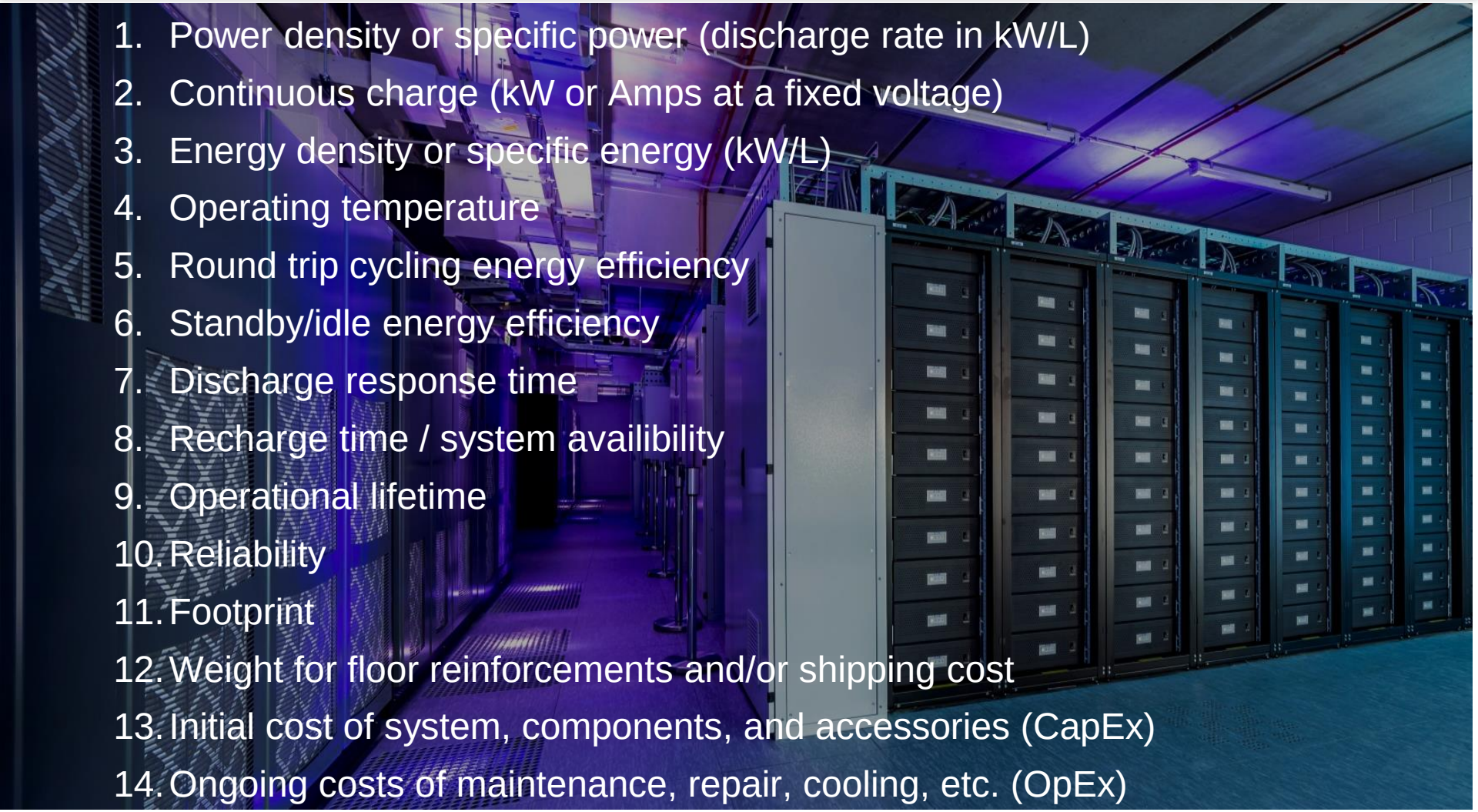
Key Parameters To Consider By Selecting The Energy Storage Technology



1. Power density or specific power (discharge rate in kW/L)
2. Continuous charge (kW or Amps at a fixed voltage)
3. Energy density or specific energy (kW/L)
4. Operating temperature
5. Round trip cycling energy efficiency
6. Standby/idle energy efficiency
7. Discharge response time
8. Recharge time / system availibility
9. Operational lifetime
10. Reliability
11. Footprint
12. Weight for floor reinforcements and/or shipping cost
13. Initial cost of system, components, and accessories (CapEx)
14. Ongoing costs of maintenance, repair, cooling, etc. (OpEx)

Most Common Energy Storage Technologies

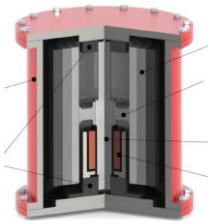
1. VRLA Battery – 50% market share, but decreasing
2. LiIon Battery
3. Supercapacitor
4. Flywheel
5. Diesel Generator/Turbines *
6. Hydrogen Fuel Cell *

High power density technologies gaining share from VRLA mainly due to fast up to speed gensets

* : not discussed as they are slow response time, long term energy provider devices

High Power Density Energy Storage Technologies

Key Characteristic	Units	Supercapacitor - Electrostatic -	Li-ion Batteries - Electrochemical -	Flywheel - Kinetic -
Voltage per base unit	V	2.5-3	3.6-4.2	400-500
Cold Operating Temp	°C	**-40**	-20	-10
Hot Temperature	°C	**+70 (85)**	+45	+40
Cycle Life		**>1,000,000**	10,000	unk
Calendar Life	Years	**5-20**	3-10	**20**
Energy Density	Wh/L	1 – 10	**250-650**	0.6 – 1.2 incl converter
Power Density	W/L	**1000 – 10,000**	850 - 3000	98 - 275
Efficiency	%	**>98**	80 - 90	98
Charge Rate	C/x	**>1,500**	<40	~4
Discharge Time		Sec or Minutes	**Hours**	Sec or Minutes
Cost per kWh	$	10.000-15.000	**100-500**	2.000-5.000
Cost per kW	$	**0.1-0.2**	100-500 (1C)	300-500 (many factors)



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High Power Energy Storage - Examples

Specification	Units	Supercaps (30 XLM unit)	Lithium-ion	Flywheel
Voltage Range	Vdc	570 – 360	538 – 410	520 - 400
Temperature Range	°C	-40 to +65C	+18 to +28	-10 to +40
Max Power	kW	300	150	300
Energy Storage	kWh	2.09	32.6	1.67
Design Life @ 28C	Years	20	15	20
Recharge Rate	Amps	150	22	15 to 50
Dimensions (W x D x H)	cm	80 x 85 x 213	65 x 60 x 229	76 x 76 x 187
Weight	Kg	750	550	760
Advantages		• Maintenance free • Low or no need for HVAC • No disposal issues • Easly scaleable • Safe operation • Fast recharge in seconds	• Lowest kWh cost overall • High reliability with advanced cell monitoring	• Very good cost/kW and cost/kWh performance combination
Disadvantages		• Most expensive per KWh	• Specific HVAC requirements especially in public access areas additional fire safety	• Less scaleable • High installation cost (large and heavy one piece equipment, shipping cost) • Expensive regular maintanance • High energy consumption through the lifetime

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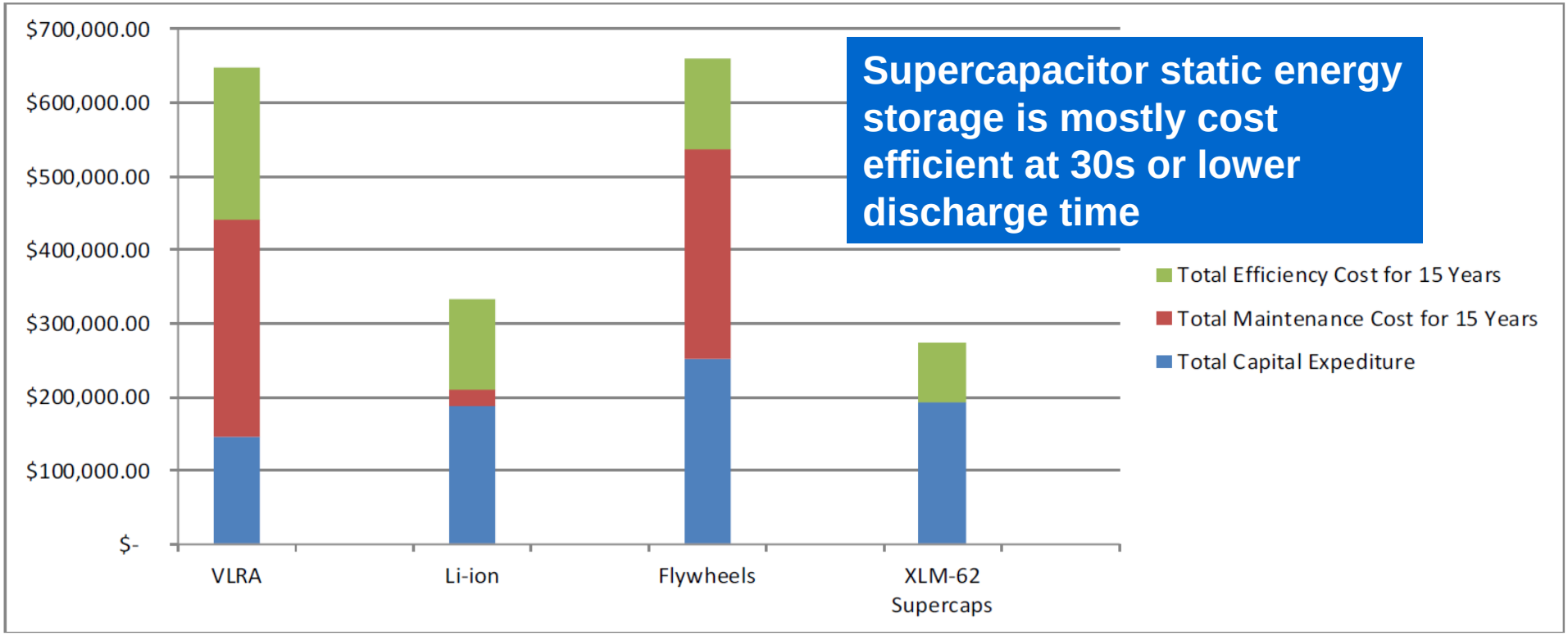
TCO For 600kVA – 30s Energy Storage Unit for 15yrs Lifetime



Supercapacitor static energy storage is mostly cost efficient at 30s or lower discharge time

Eaton's online TCO calculation tool is soon available @ https://www.eaton.com/us/en-us/products/electronic-components/supercapacitor-tco-tool.html

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Supercapacitors Energy Storage Applications On An Economical Scale

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Reliable Back Up Power When Needed

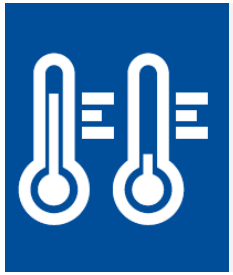
Use Cases Of Supercap Power:

Short back-up times

- When primary power is interrupted, Eaton's Supercapacitors will bridge the gap until generator starts up.

Short power interruptions

- Blackouts, brownout, glitches autoreclosure events
- Provides protection until mains power is restored



High temperature environments

- Where batteries just won't survive
- Supercapacitors are specified from -40C to +65C

Power peaks

- When short repetitive power peaks are the problem – Eaton Supercapacitors provides a reliable power buffer

Reducing CAPEX

Lower infrastructure costs due higher temperature capability

- Location can be optimized with less cooling and no need for hydrogen venting
- Supercaps also weight less than batteries or flywheels thus no need to reinforce floor

Long lifetime

- +15years operating lifetime, up to 20years at +25C

Greater scalability - example for modular setup:

- Easily scales in strings of 10 modules
- 1 string is ~100kW / 10sec
- Decay of capacitance over 20years can be compensated by installing fresh caps parallel to existing ones

Lowering OPEX

NO MAINTENANCE

Unlike batteries or rotating devices Supercapacitors do not need scheduled maintenance.

SPARE PARTS

No maintenance means no spare parts no lead time for spares no inventory stock.

HIGH EFFICIENCY

Operating losses of Supercapacitors are minimal whereas rotating solutions consume continuously energy to spin the rotating mass. Total system efficiency will outrank rotary systems by far.

Grid Storage And Ancillary Services

XLM-62

XLR-48
XLR-51

Frequency regulation & microgrid

- Challenges
  - Efficient balancing of supply and demand
  - Increase in Distributed Energy Resources (DER)
  - More sensitive demand loads
  - High ramp rate supply and demand with renewables and large consumers
- Why Eaton
  - High peak power and efficiency
  - Reliability and long lifetimes
  - Deep applications support
  - Complementary products for all-in-one solution

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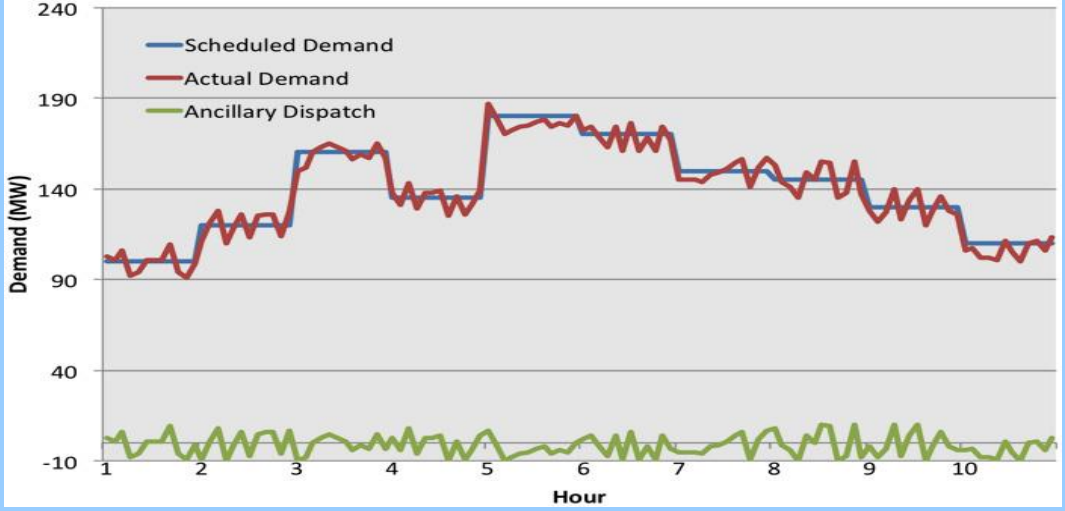
Ancillary services

- Matches the instantaneous demand and supply for the grid
- Provides frequency regulation to ensure quality power transmission



- Supercaps take place of natural gas turbines and spinning reserves
- Reduces greenhouse emissions and start/stop of turbines

Renewable Energy

XLM-62

XLR-51

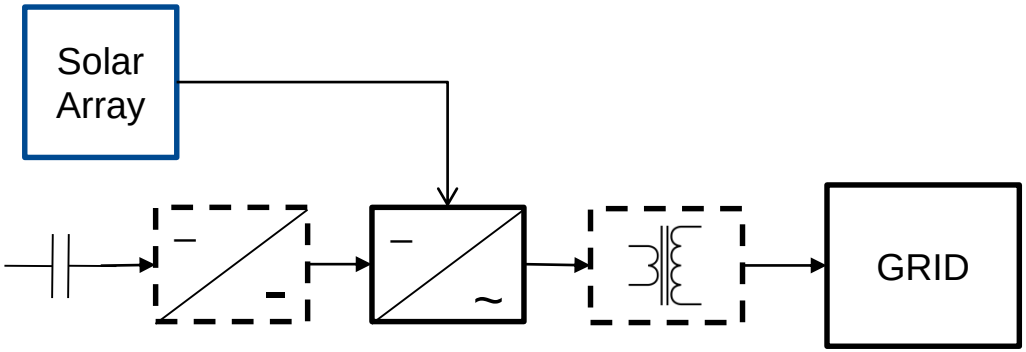
Solar and wind firming

- Challenges
  - Inconsistent renewable output
  - Frequent charge/discharges for firming
  - Reduce O&M expenditures
- Why Eaton
  - High peak power and efficiency
  - Maintenance free operation
  - Reliability and life time
  - Deep applications support

Solar Powered Microgrid Example

50kW, 19 seconds, 10 modules

- Solar, Li-ion battery, supercapacitors, solar inverter
- Demonstrate supercapacitor modules
  - Firming solar output (30% efficiency improvement)
  - Protecting Li batteries
  - Control optimization
- Supercapacitors absorb voltage dropouts



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Traction wayside energy regeneration

XLM-62

XLR-48
XLR-51

Rail, trolley, subway electrification

- Challenges
  - High power required for acceleration
  - Grid voltage control
  - Energy efficiency/savings
  - Maximum power capture
- Why Eaton
  - Applications support
  - Quick charge capability
  - Adjacent Eaton equipment & services
  - High and low duty cycle products

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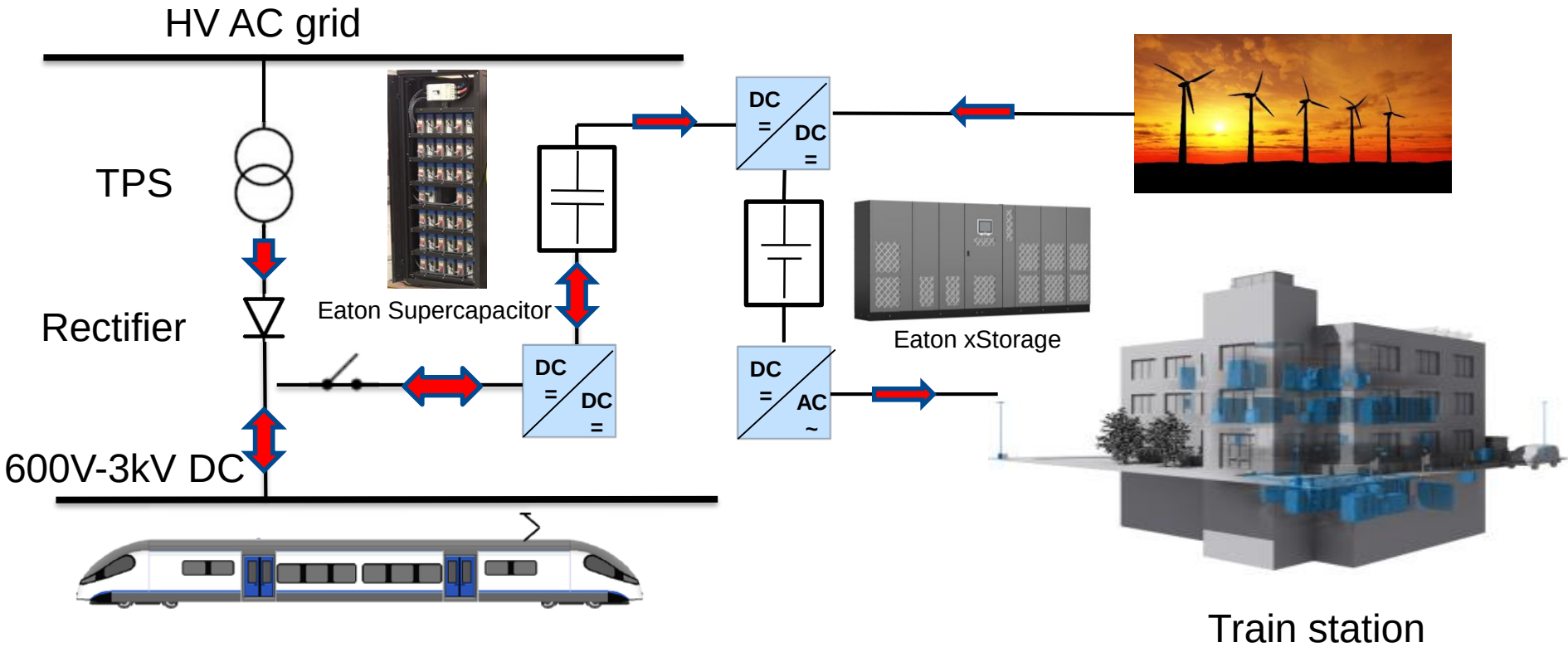
Trackside ESS connected to renewables



Short Duration UPS

Critical facility power quality

- Challenges
  - Poor grid reliability
  - Short power drops cause hours of downtime
  - High maintenance backup solutions
  - Required short duration ridethrough
  - Hot environments
  - Semi F-47 Ridetrough
- Why Eaton
  - Long life alternative to batteries, especially at higher temperatures
  - Low maintenance compared to fly wheels
  - High reliability

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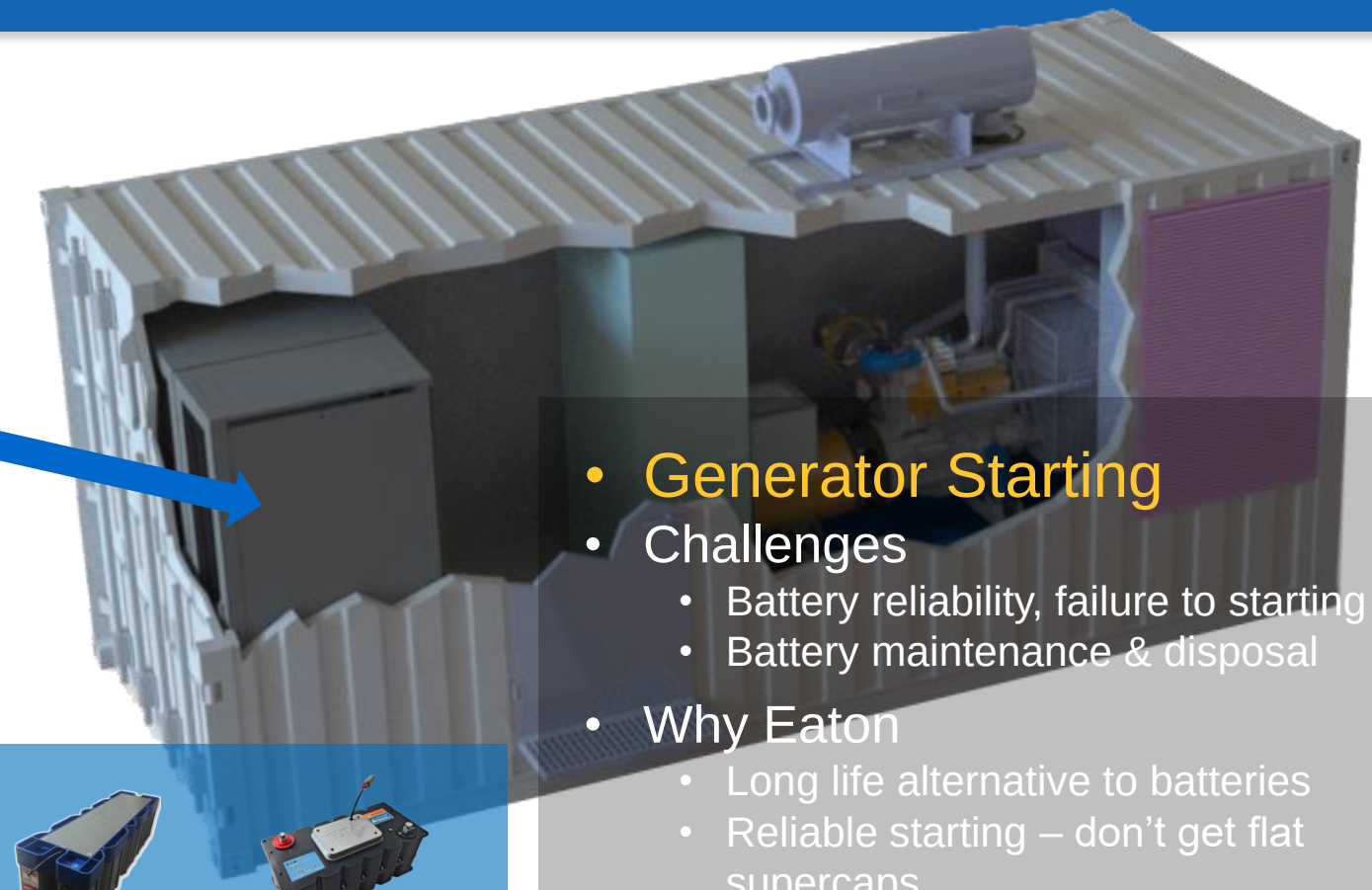
Bridge Power Emergency Back-Up Generators



- Generator Starting
- Challenges
  - Battery reliability, failure to starting
  - Battery maintenance & disposal
- Why Eaton
  - Long life alternative to batteries
  - Reliable starting – don't get flat supercaps
  - Maintenance free
  - No heavy metals, no recycling requirements

- XLM-62R1137A-R
- XLR-48R6167-R

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Heavy material handling peak power support

Harbor crane & large lifting systems

- Challenges
  - High power required for heavy loads
  - Maximize energy efficiency
  - Shock and vibration, reliability
  - Low and high temperature
- Why Eaton
  - High peak power and efficiency
  - Reliability and life times up to 20 y
  - Regenerative energy capture
  - Deep applications support
  - Cabinet level solutions

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Learn more at:

www.eaton.com/supercapacitors

Or contact in EMEA:

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Thank You!