The challenge of renewable energy storage



The topics of today

- Renewable energy storage
- What is a rechargeable battery?
- Lead Acid and Lithium Ion batteries and their reaction mechanism

- The **Lead Acid VRLA battery** workhorse
- How we have improved it to give it better stability

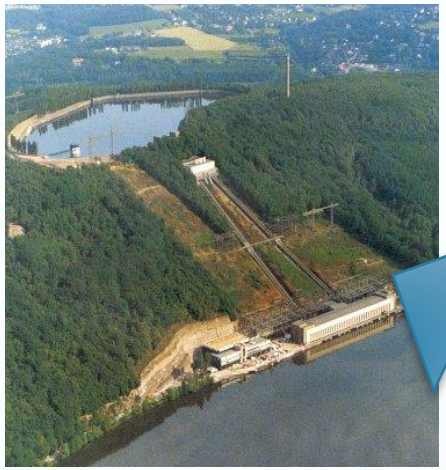
- The **Lithium-Ion battery** workhorse
- The new kid in the neighborhood and its sensitivities

- SMART GRID – **Energy Storage System**
- The way ahead for Smart Grid/ Energy Storage Application.

- Q&A - anytime



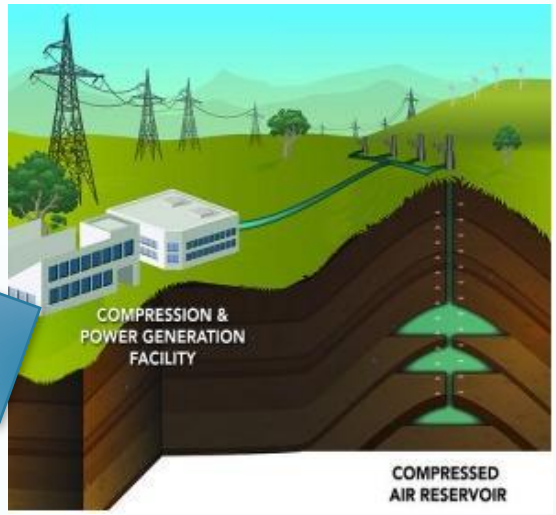
What to do with all this energy?



Pumped Hydro







Compressed Air



Thermal energy storage

Batteries





Why batteries ?

- Can be easily sized to meet the local storage needs (3kWh – 15MWh)

- Store electricity reversibly as chemical energy
  (DC-in <–> Production of defined chemical species <–> DC- out)

- Can release energy without any time lag (to full power <<16ms)

- Have a high round-trip energy efficiency (>85%)

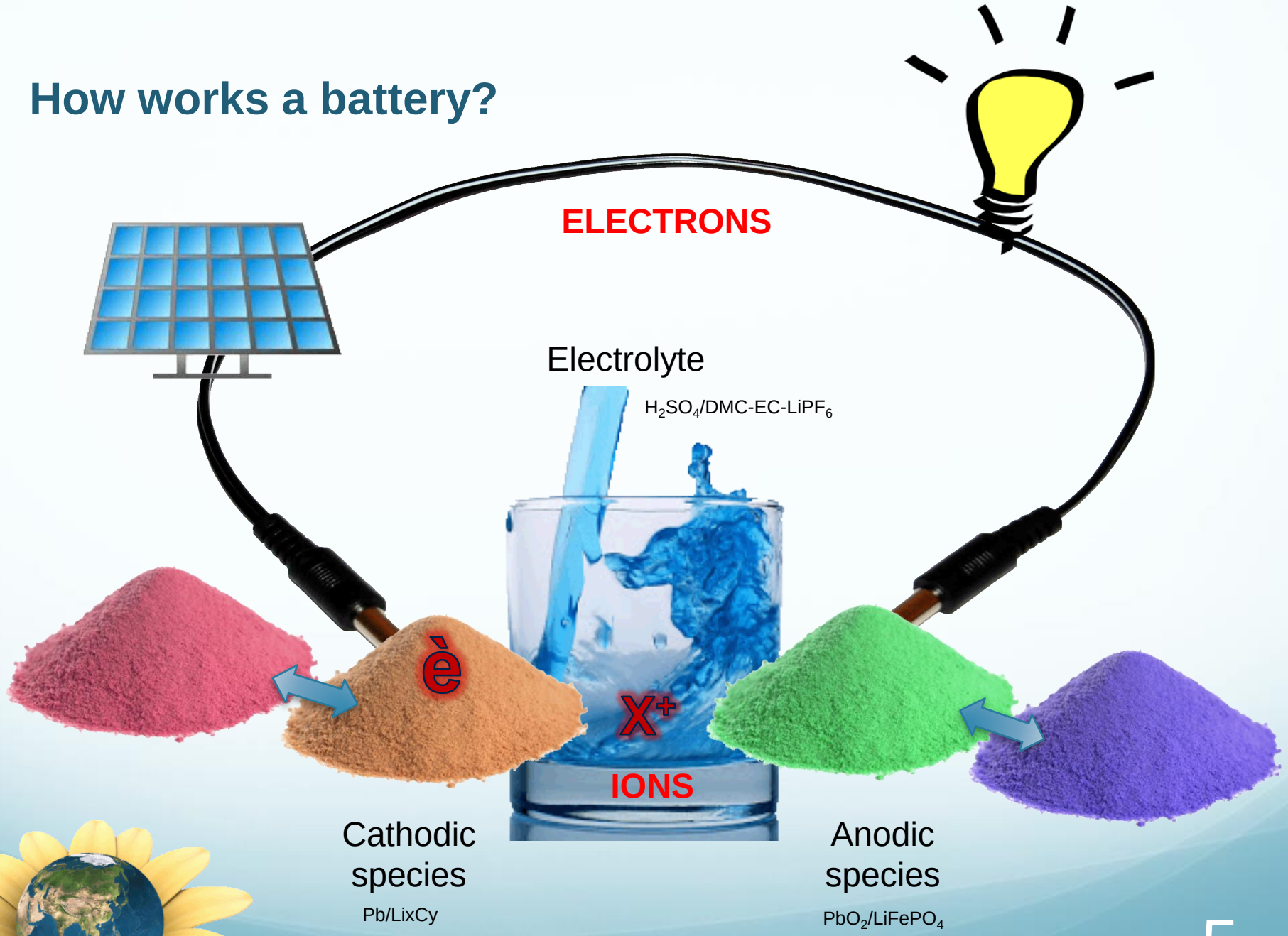
- Can be operated with minimal supervision

- Have reasonable costs per kWh energy stored

- Can release energy at a wide range of power levels



How works a battery?

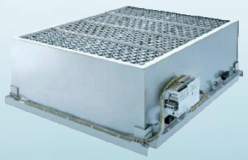


What batteries ?

Property	Units	Lead	Lithium	NaS	NaNiCl	V^{5+}--V^{2+}
Energy density	Wh/kg	25	140	150	100	20
	Wh/l	75	360	170	150	10
Footprint 10kWh/1.8m	m^2	0.22	0.05	0.10	0.11	1.7
Capex	US$ per kWh	150	700	400	500	500
Capacity turnover	X * nominal	≈1000x	≈2000x	≈3000x	≈2500x	≈10000x
Suppliers	Available from	Many worldwide	Many	One	Two	Few
Scalable	kW/kWh	Easy	With precautions	Within limits	Within limits	Only scaling-up











The Lead Acid VRLA workhorse

VRLA



AGM GEL



VALVE REGULATED LEAD ACID BATTERY WITH **A**BSORBENT
GLASS **M**AT OR SiO_2-SULFURIC ACID **GEL**

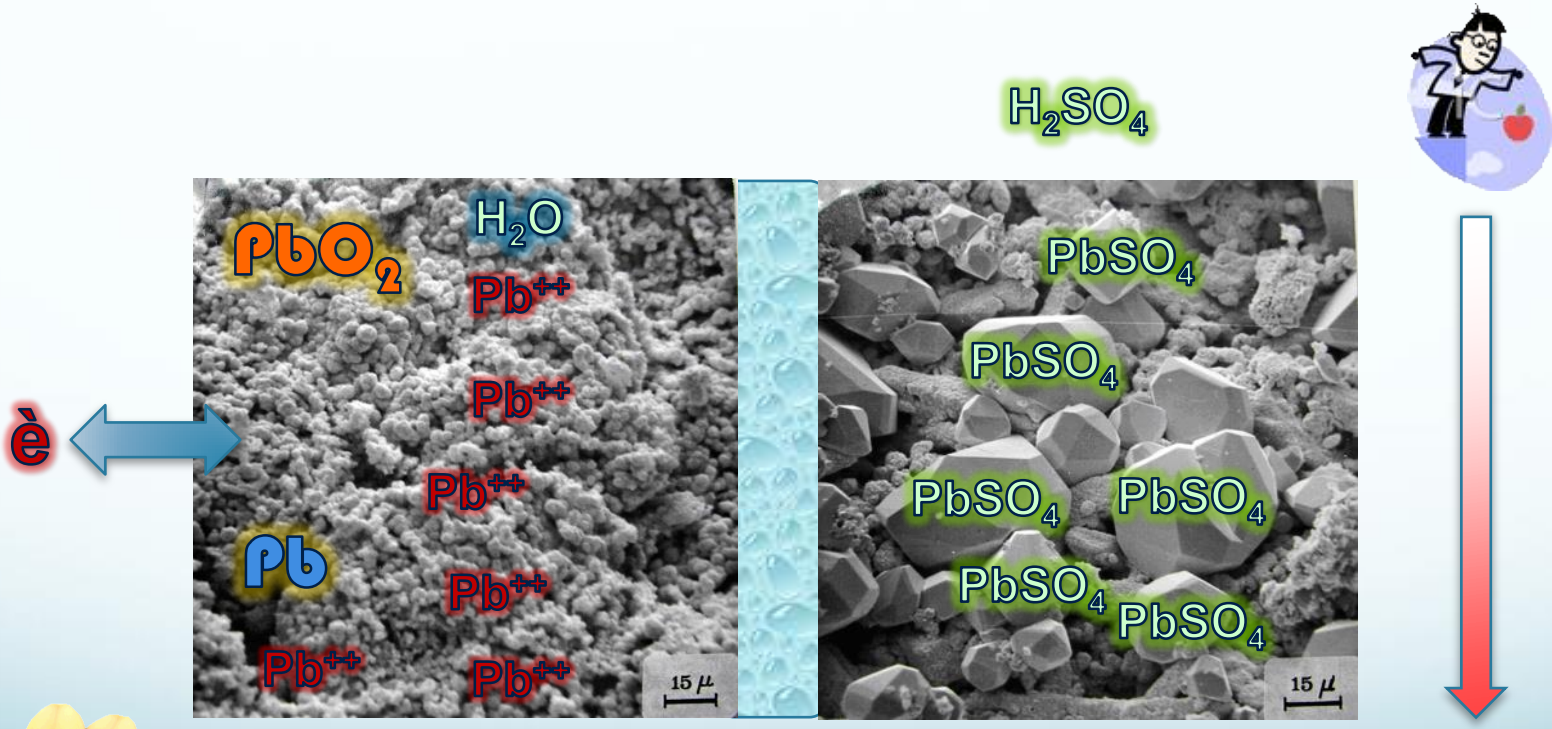


Reaction and structures

Lead Acid Battery

$Pb+H_2SO_4 <-> PbSO_4+2H^+$

$PbO_2+H_2SO_4 <-> PbSO_4+2H_2O$



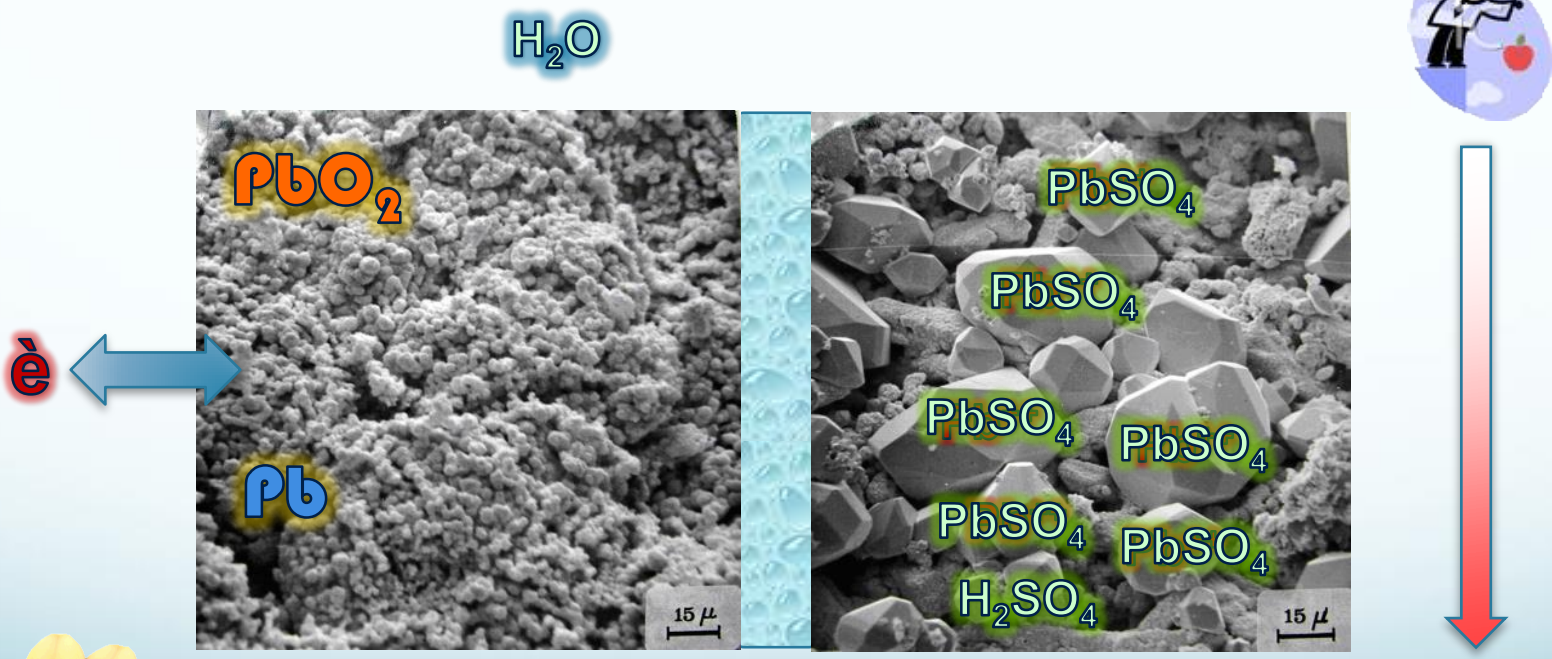
3.865g Pb + 4.462g PbO_2 + 3.659g H_2SO_4 = 11.314g $PbSO_4$ + 0.6772g H_20 per 1 Ah

Reaction and structures

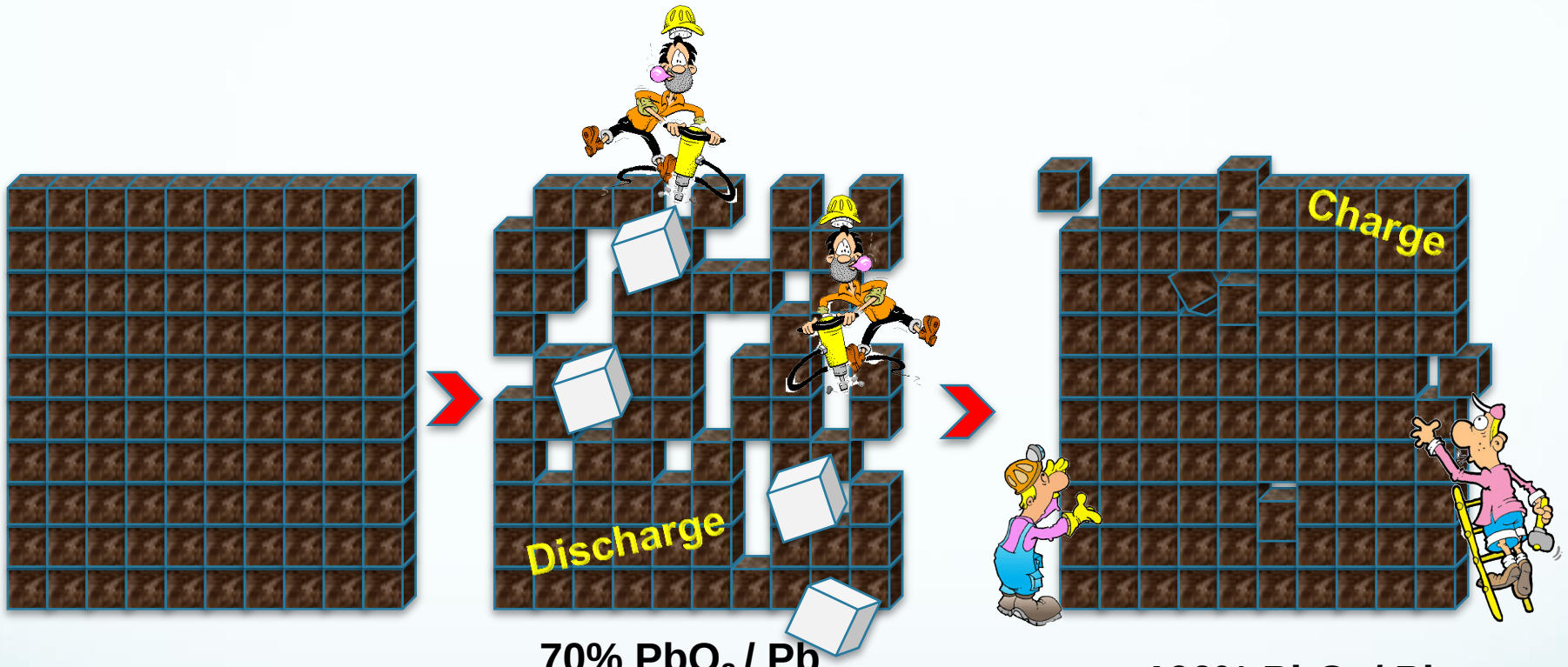
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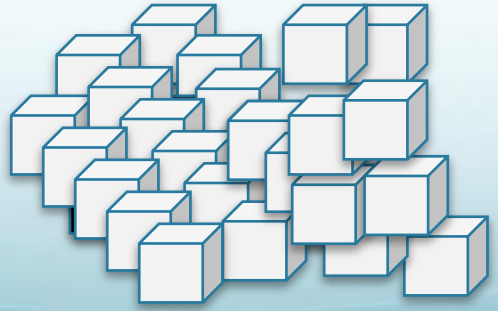
The need for perfection 1000 times over



100% PbO_2 / Pb

70% PbO_2 / Pb

<100% PbO_2 / Pb



30% $PbSO_4$



Love at first sight ?!



- ≈ 32% lower weight per Ah
- ≈ 45% smaller volume per Ah
- ≈ 36 % higher 1h rate current capability
- Position independent operation
- Only 1/6 of air exchange volume needed
- No water topping-up needed
- No electrolyte leakage
- Fast on-site – air freight capable
- No activation procedure needed
- > 1 year storage capability
- Low cost of ownership
- Worldwide availability
- Attractive form factors (H x W x L)



Strengthen the box and the muscles





Lay-out adaptation, 105°C
Vicat plastic and HT AGM

+75°C
15 days



12V-100Ah
19”- 400mm

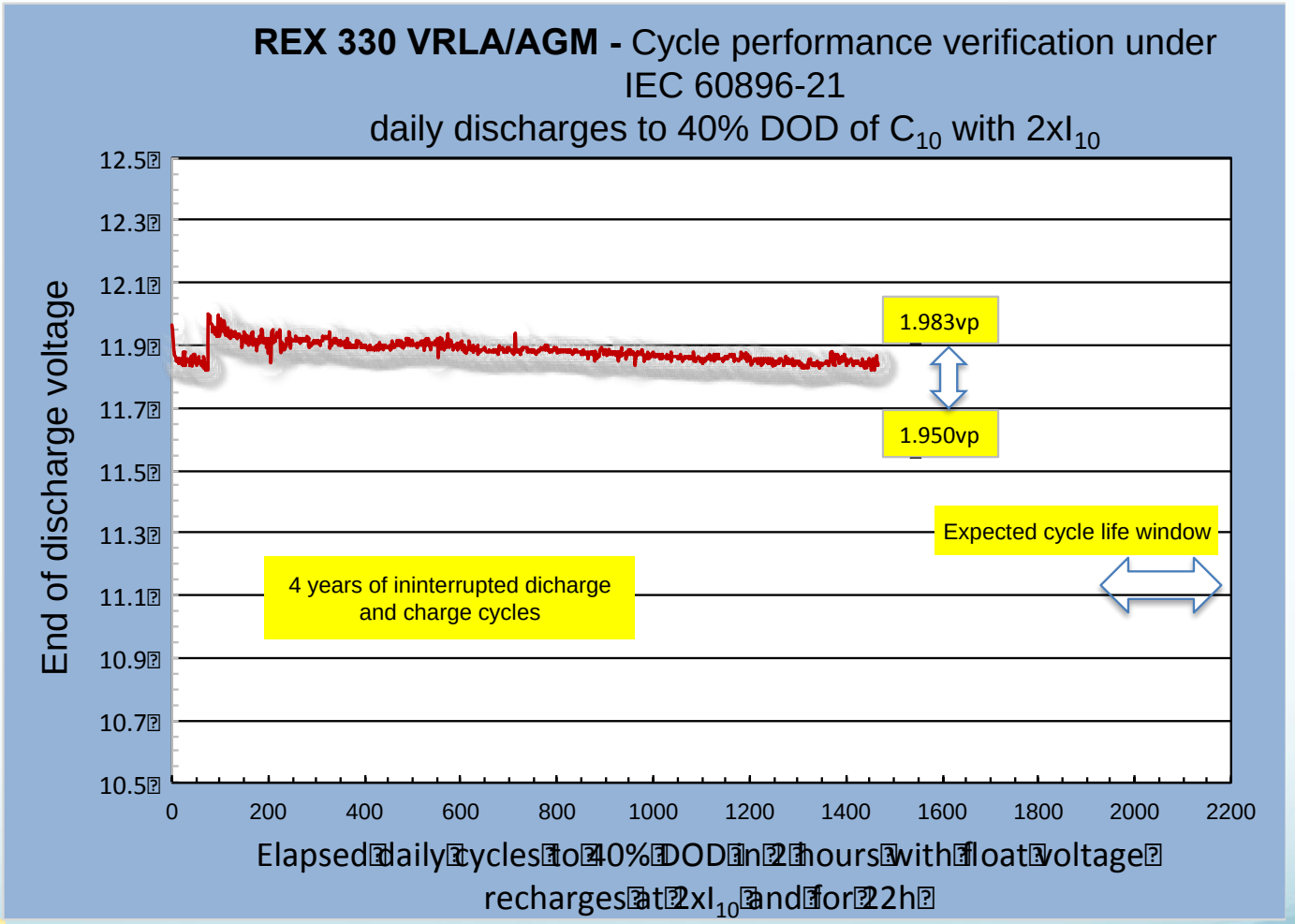


12V-150Ah
23”- 600mm



VRLA design – back to have it working!

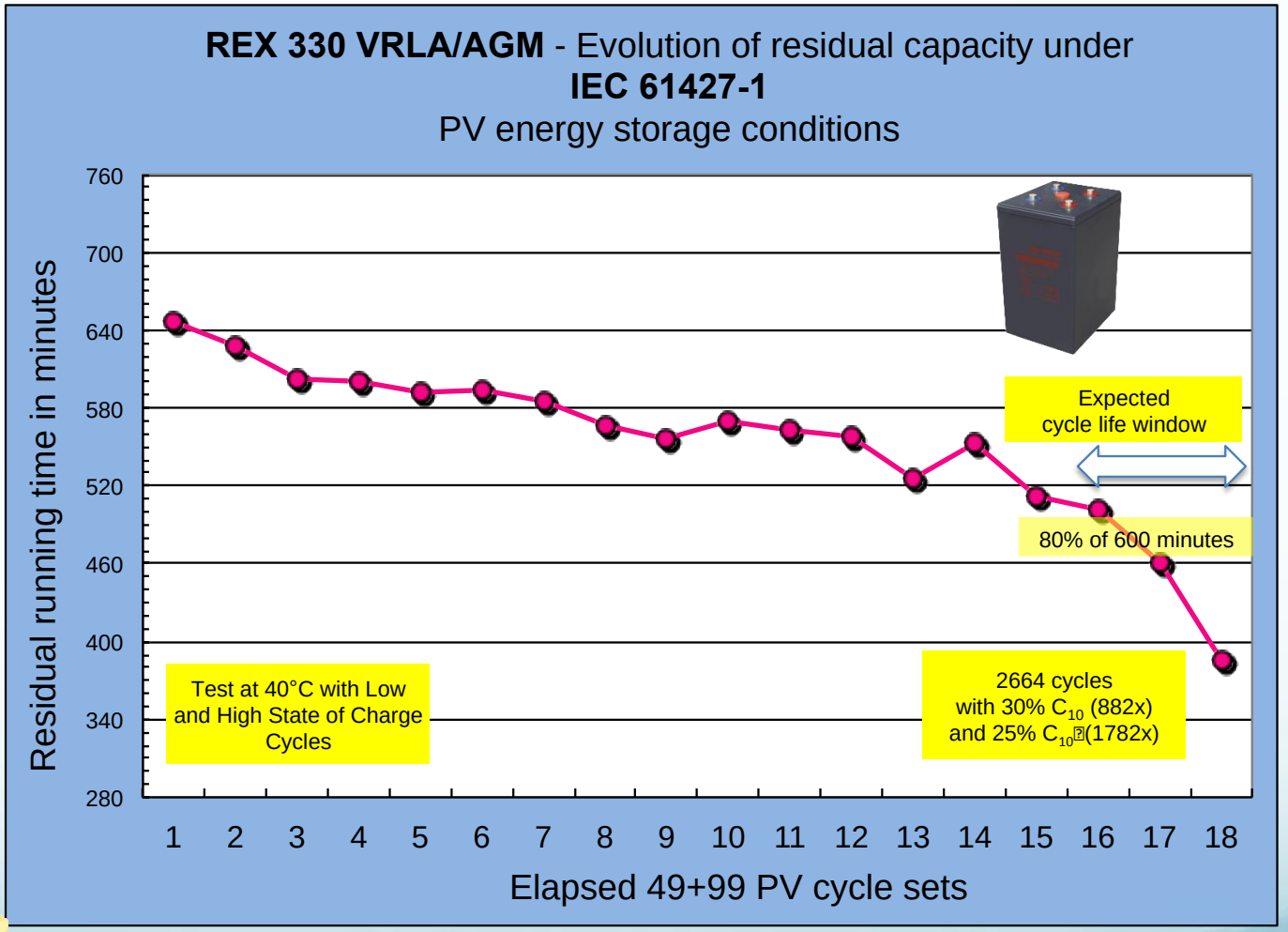






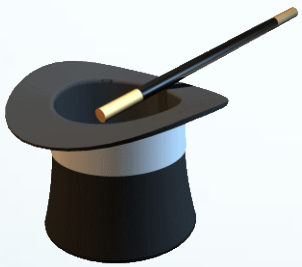
VRLA design – back to have it working!

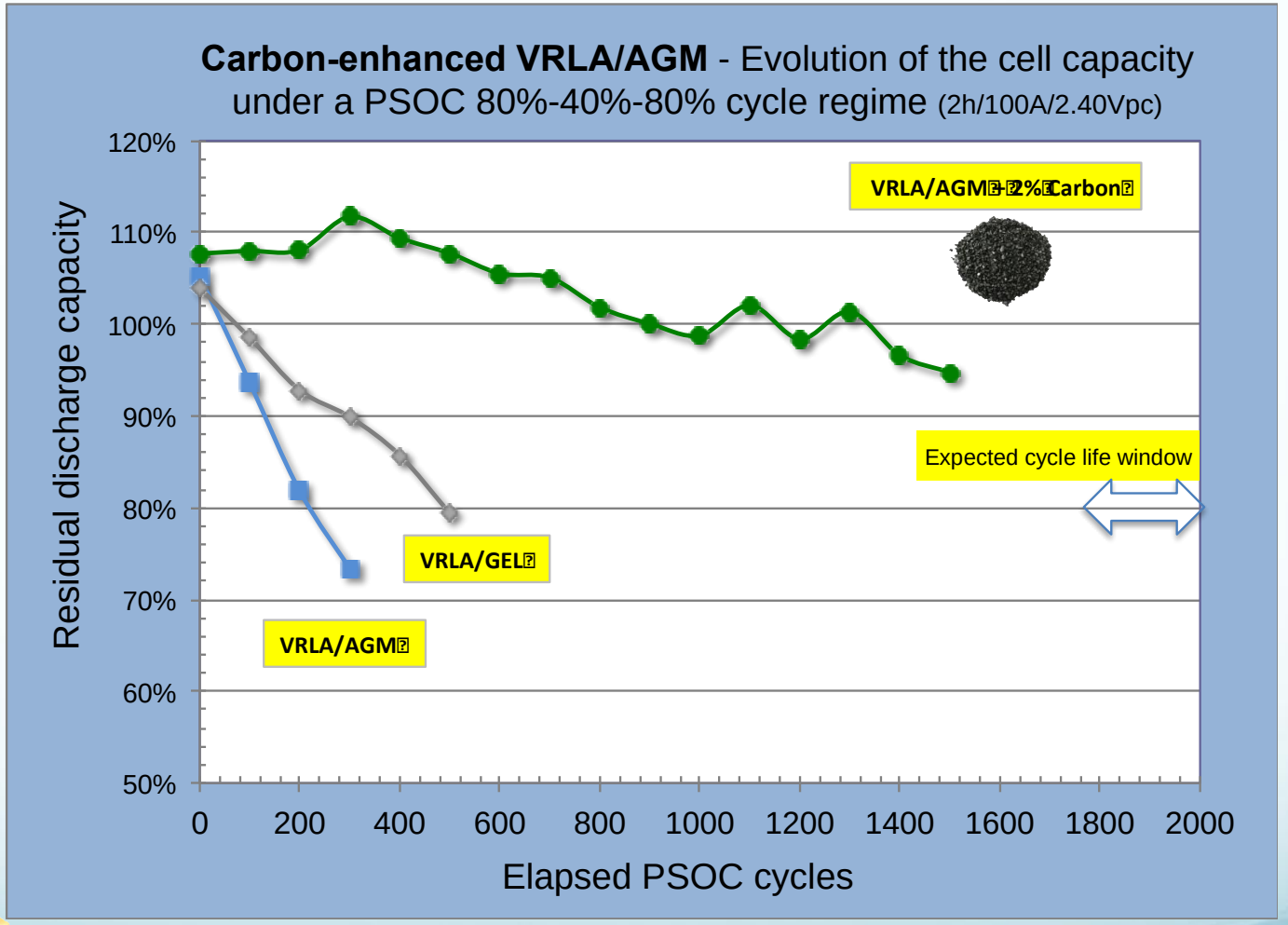






VRLA design – back to have it working!



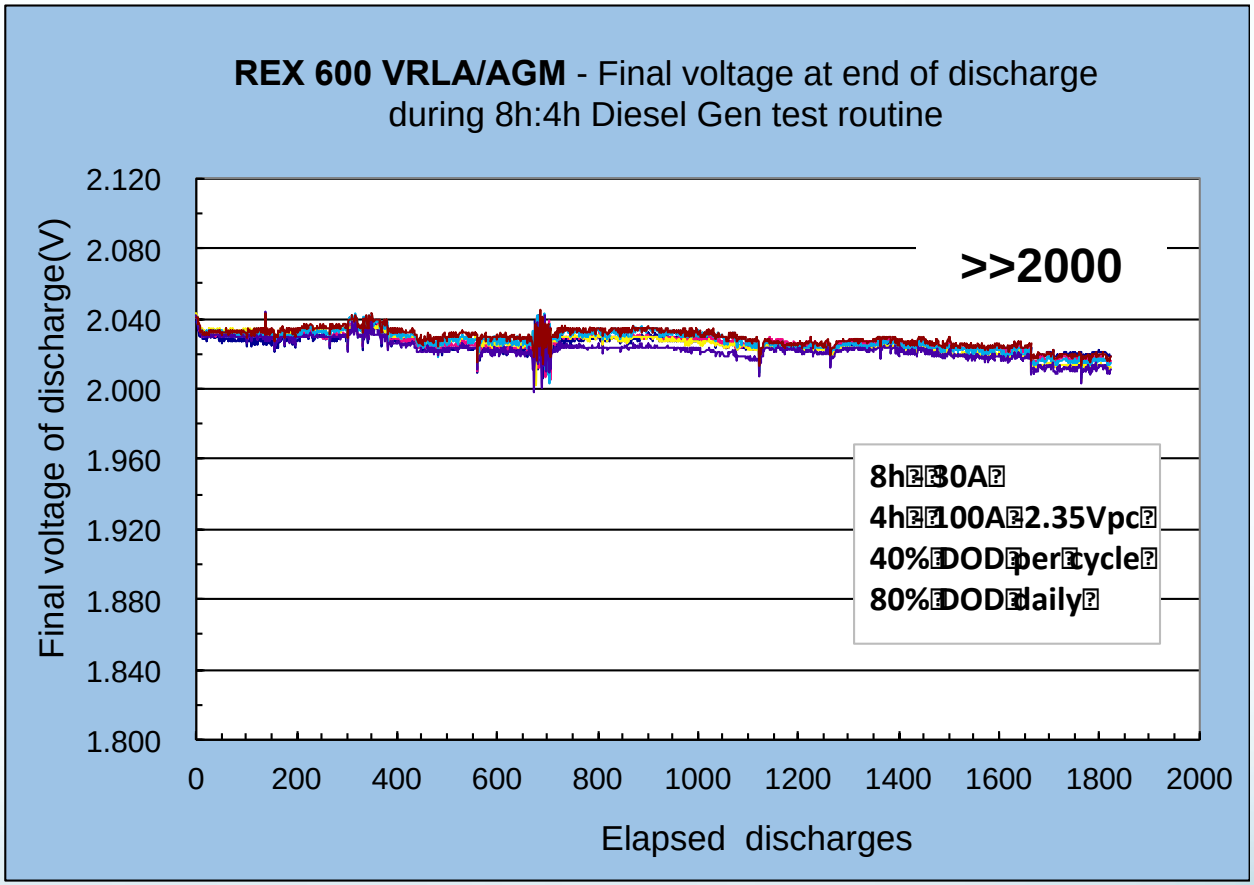




VRLA design – back to have it working!







REX series when Narada is strong

Applications in hybrid system











- Battery + DG
- Battery + DG + Solar
- Battery + DG + Solar + Wind
- Battery + DG — Wind
- Battery — Solar
- Battery — Solar + Wind

REX series when Narada is strong

Narada

Applications in hybrid system













Battery + DG

Battery + DG +

Battery + DG +

Battery + DG

Battery

Battery

REX series when Narada is strong

Applications in hybrid system













- Battery + DG
- Battery + DG + Solar
- Battery + DG + Solar
- Battery + DG
- Battery — Solar
- Battery — Solar

REX series when Narada is strong

Applications in hybrid system











Battery + DG

Battery + DG +

Battery + DG + Solar + Wind

Battery + DG

Battery

Battery



REX series when Narada is strong

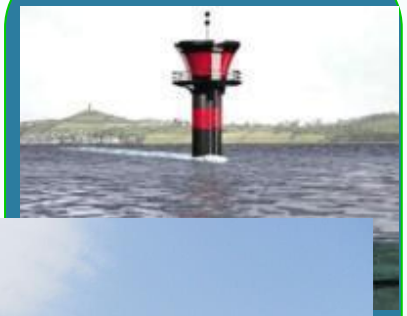
Applications in hybrid system











Battery + DG

Battery + DG +

Battery + DG +

Battery + DG

Battery

Battery



Solar

REX series when Narada is strong

Narada

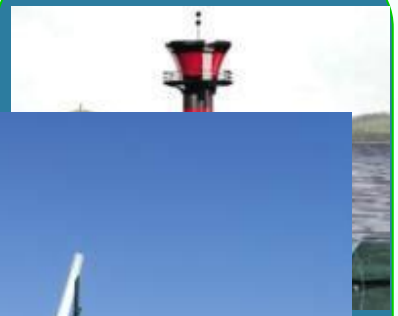
Applications in hybrid system











Battery + DG

Battery + DG +

Battery + DG +

Battery + DG

Battery

Battery

Solar + Wind

The Lithium Battery workhorse

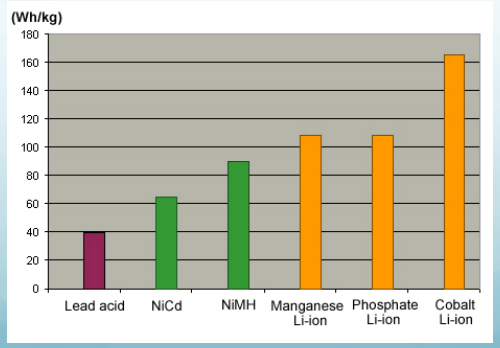
Li-ION

$LiCoO_2$



$LiFePO_4$



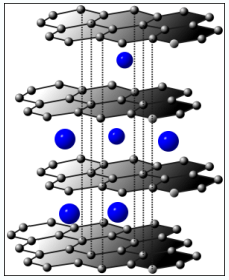


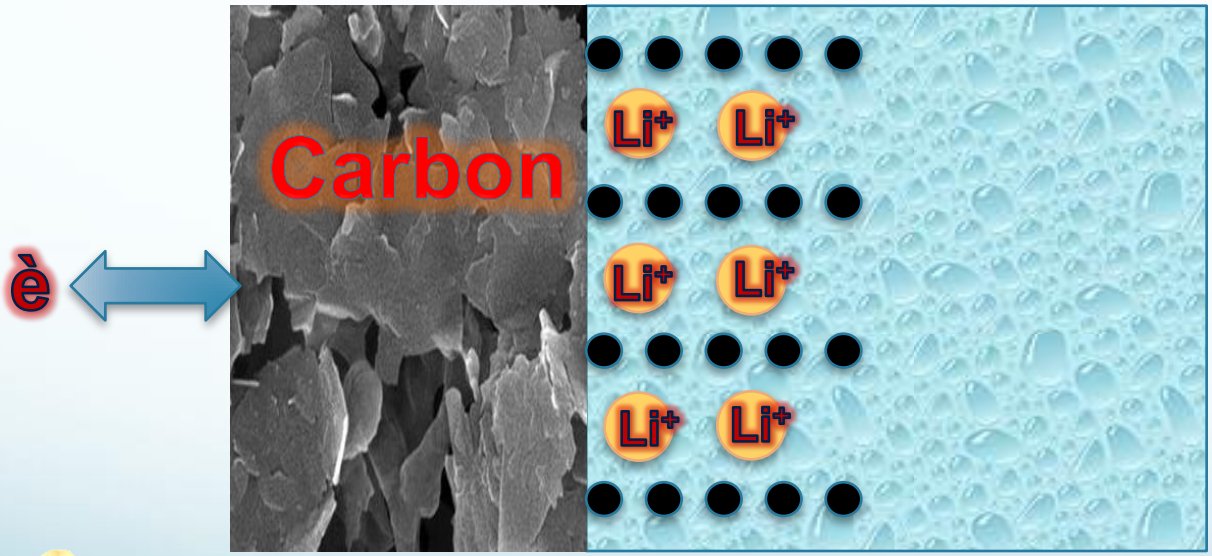


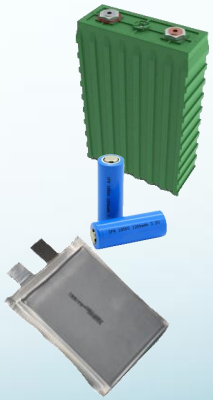
Reaction and structure

Lithium Ion Battery

$\gamma C + xLi^+ <-> Li_xC_y$







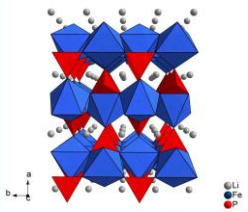


2.68g Li_YC_6 + 5.88g $LiFePO_4$ per 1 Ah

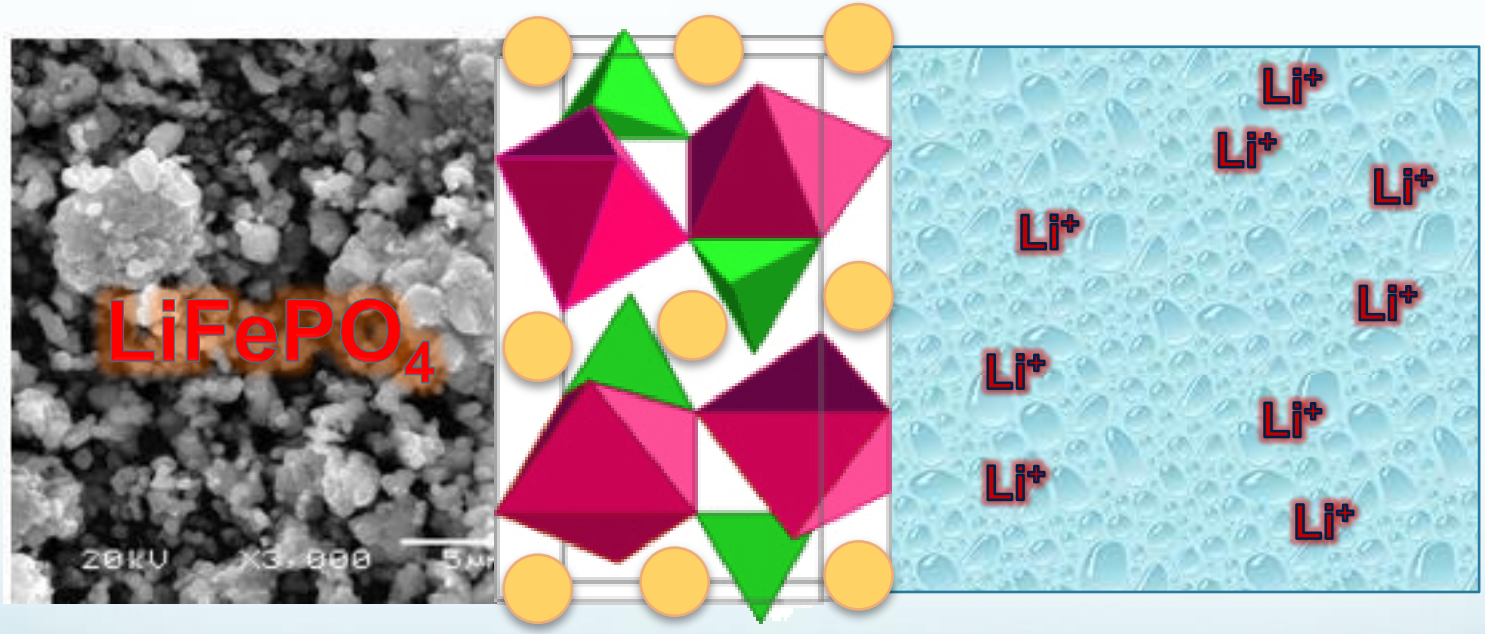
Discharge reaction sequence

Reaction and structure

Lithium Ion Battery



$LiFePO_4 <-> Li_{1-x}FePO_4 + xLi^+$



Discharge reaction sequence

Not going over the cliff!

Overcharge

Cell imbalances

Overdischarge

Loss of BMS

Puncture/Crush



Lithium dendrites

Hollow promises

Harvesting and storing green energy!

The new kid in the neighborhood

Packaged $LiFePO_4$ systems







Harvesting and storing green energy!

General Specifications

Type	48NPFC10	48NPFC20	48NPFC30	48NPFC40	48NPFC50	48NPFC60
Nominal voltage (V)	48	48	48	48	48	48
Nominal capacity	10	20	30	40	50	60
Charge Voltage (V)	54.0 +/- 0.5	54.0 +/- 0.5	54.0 +/- 0.5	54.0 +/- 0.5	54.0 +/- 0.5	54.0 +/- 0.5
Max. Charge current (A)	5.0	10.0	10.0	20.0	20.0	20.0
Optional charging current limit(A)	2.0	5.0	5.0	10.0	10.0	10.0
Output Voltage (V)	40.5 to 54	40.5 to 54	40.5 to 54	40.5 to 54	40.5 to 54	40.5 to 54
Max. Output current (A)	10.0	20.0	20.0	20.0	20.0	20.0
Dimensions (WxDxH in mm)	442x245x44	442x245x88	442x358x88	442x390x132	442x390x132	442x390x132
Weigh (kg)	7.3	13.4	19.0	33.0	35.0	36.5

Note: (1)Nominal voltage---cell nominal voltage 3.2V, 48V battery consist of 15 cells.
(2)Nominal capacity---discharge with constant current (0.2CA) to end voltage (40.5V) at 25℃.

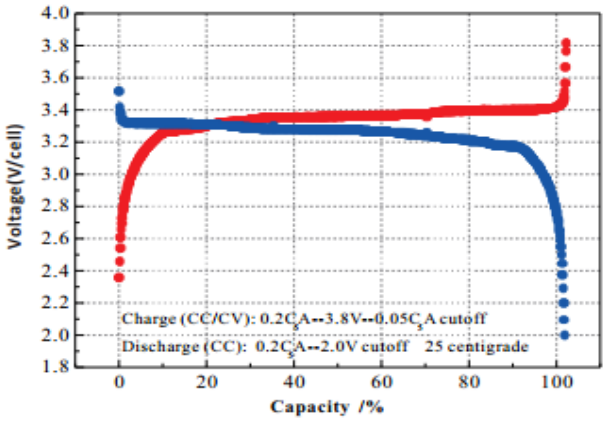




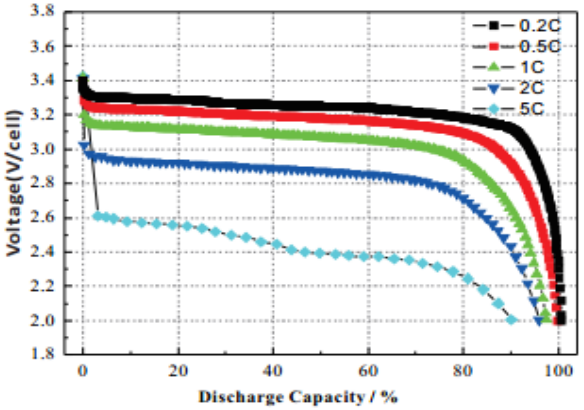
Harvesting and storing green energy!

Performance Curve

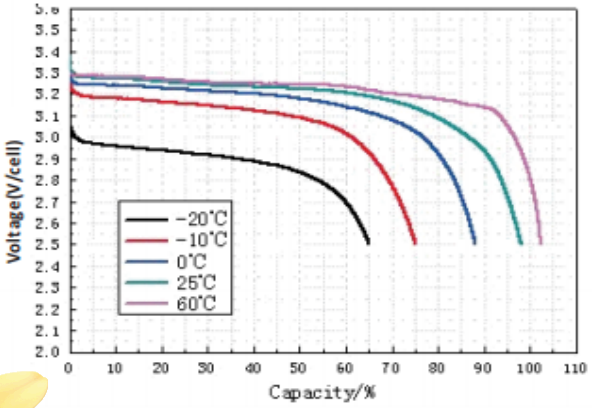
Charge and discharge voltage vs capacity(25DegC)



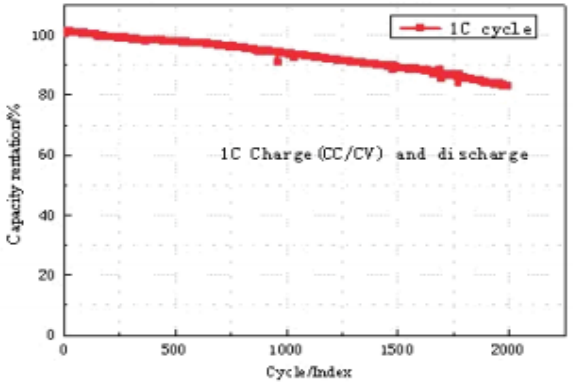
Cell discharge capacity at different discharge rate



Discharge capacity at different temperation



Cell discharge cycle at current 1CA



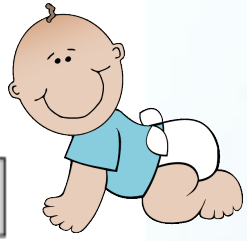




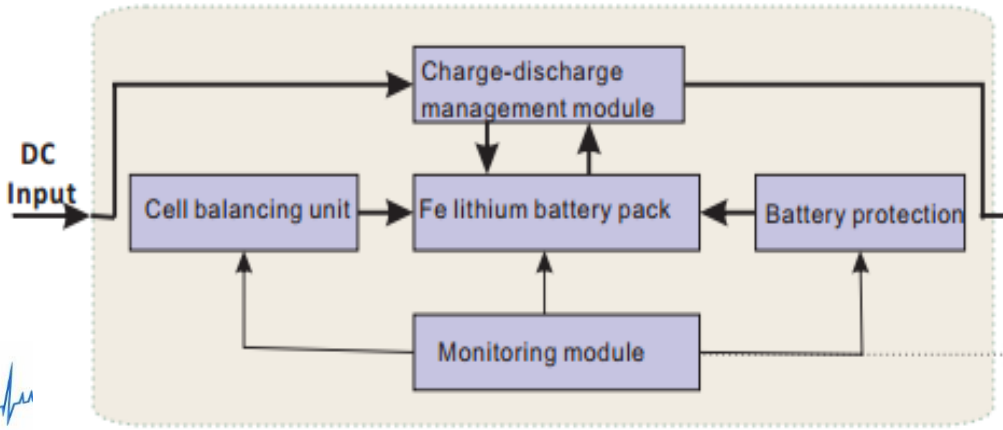
Harvesting and storing green energy!

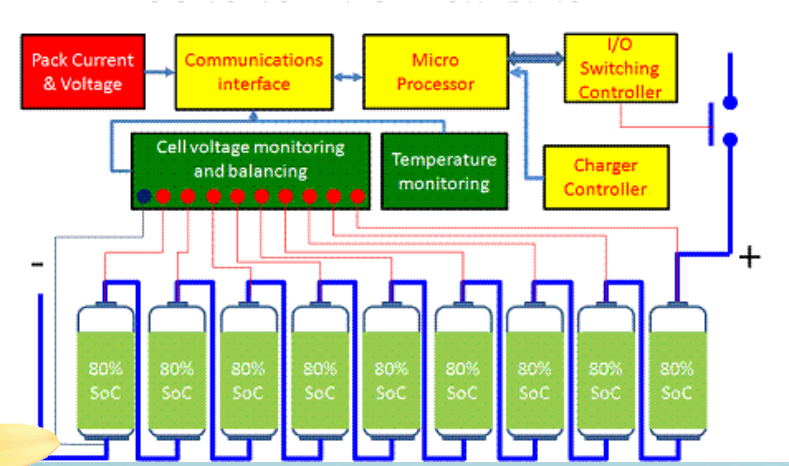
Essential BMS









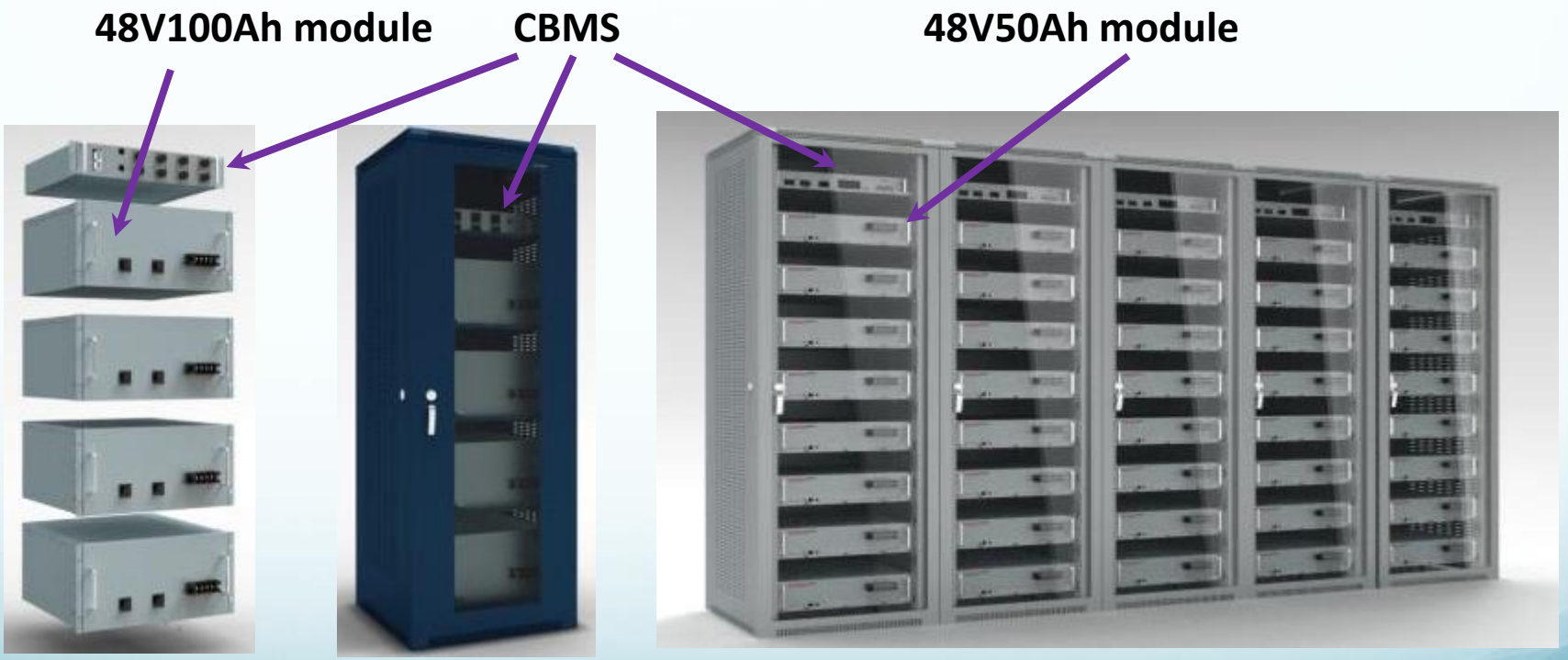






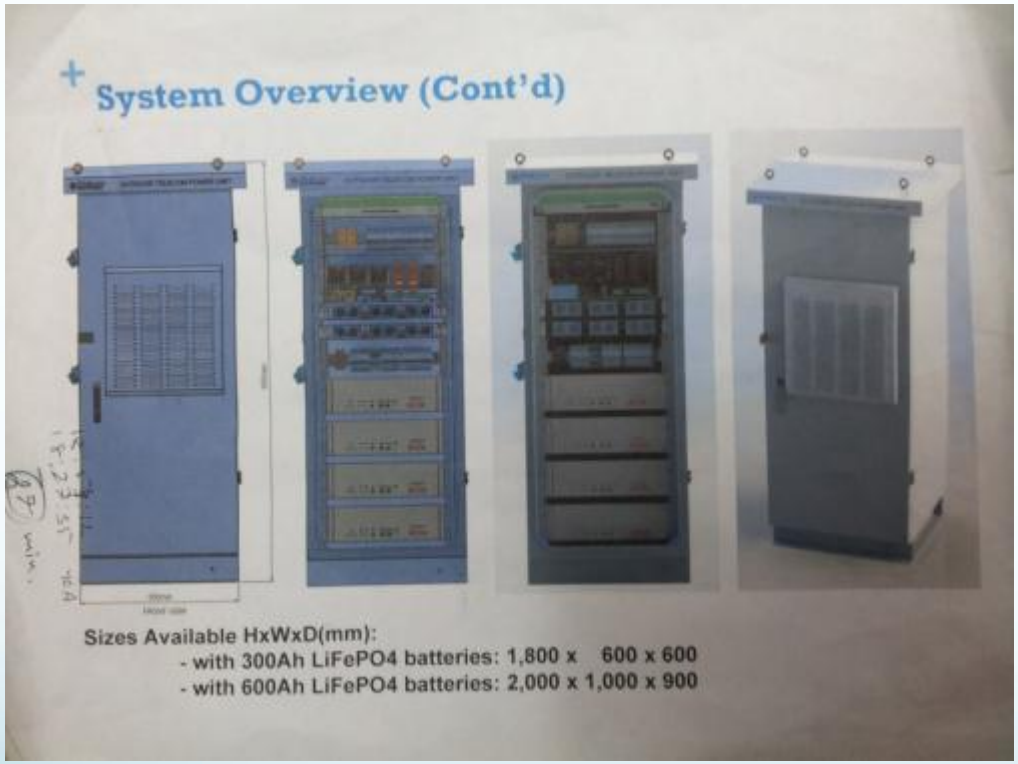
Developing Application Field

IDC battery scheme



Narada Li battery

Applications





Narada Li battery

Applications

3、FTTC（Chongqing Mobile）





Summary - Reaction and structures

Property	Lead Acid Battery	Lithium-Ion Battery
Reaction type	Oxidation - reduction Dissolution & precipitation	*Rocking chair* ion transfer Ion intercalation
Electrolyte	H_2SO_4 Reactant	DMC/EC + $LiPF_6$ Not a reactant
Material to generate 1Ah	11.98g	8.56g
Final package energy density	25 Wh/Kg	140 Wh/Kg
Technology issues	<u>Mature</u> High temperature operation Life under cyclic service Partial state of charge operation	<u>In development</u> Thermal stability Lithium deposition Oxide interaction





