Energy Storage Systems
Li-ion

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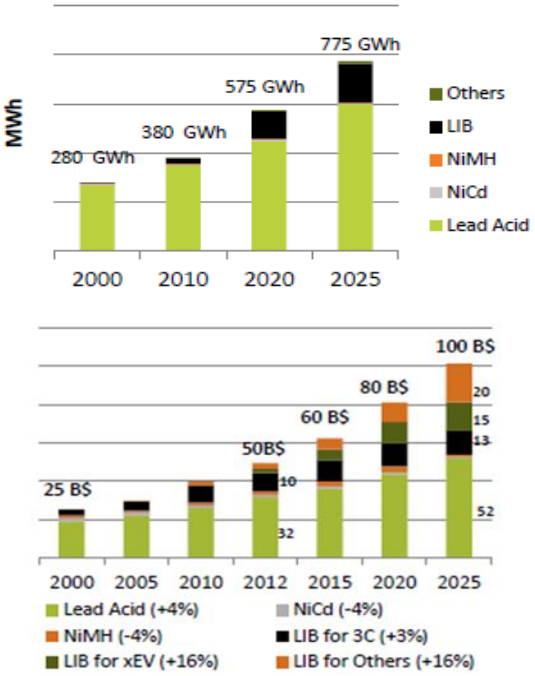
Agenda

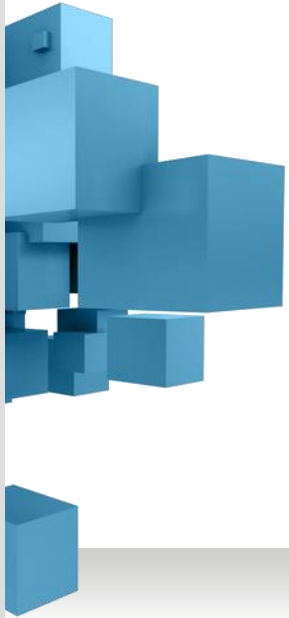
1. Battery market – Li-ion perspectives
2. Li-ion in the "consumer" market
3. Li-ion for Automotive
4. Li-ion in stationary applications and Renewable
5. Perspectives

Overview battery market (Avicenne 2013)

- Lead Acid (L/A) remains dominant technology
  - In volume and value
  - 4% of annual growth (CAGR)
- Lithium-ion (Li-ion) becomes n° 2 important
- Li-ion=50% in market value in 2025
  - Consumer 13bn$
  - Automobile - xEV 15bn$
  - "Others" - industrial 20bn$

Rechargeable battery market worldwide 2000-2025

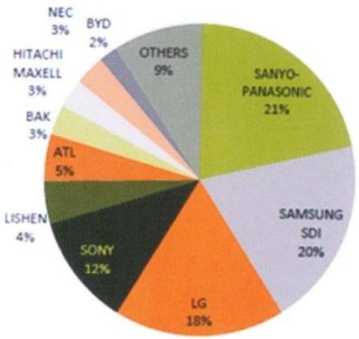




The “Consumer” market

Energy for mobile electronic

- Market totally dominated by Li-ion
- 100% are Asia supplier, mainly Japan and Korea of domestic China
- World production 4.5 B cells in 2014
- Small cells <4 Ah to 20 Ah
  cylindrical (18650), prismatic (hard shell) or pouch
- No safety problems providing
  manufacturing processes is under control
- Life duration : 2 to 3 years



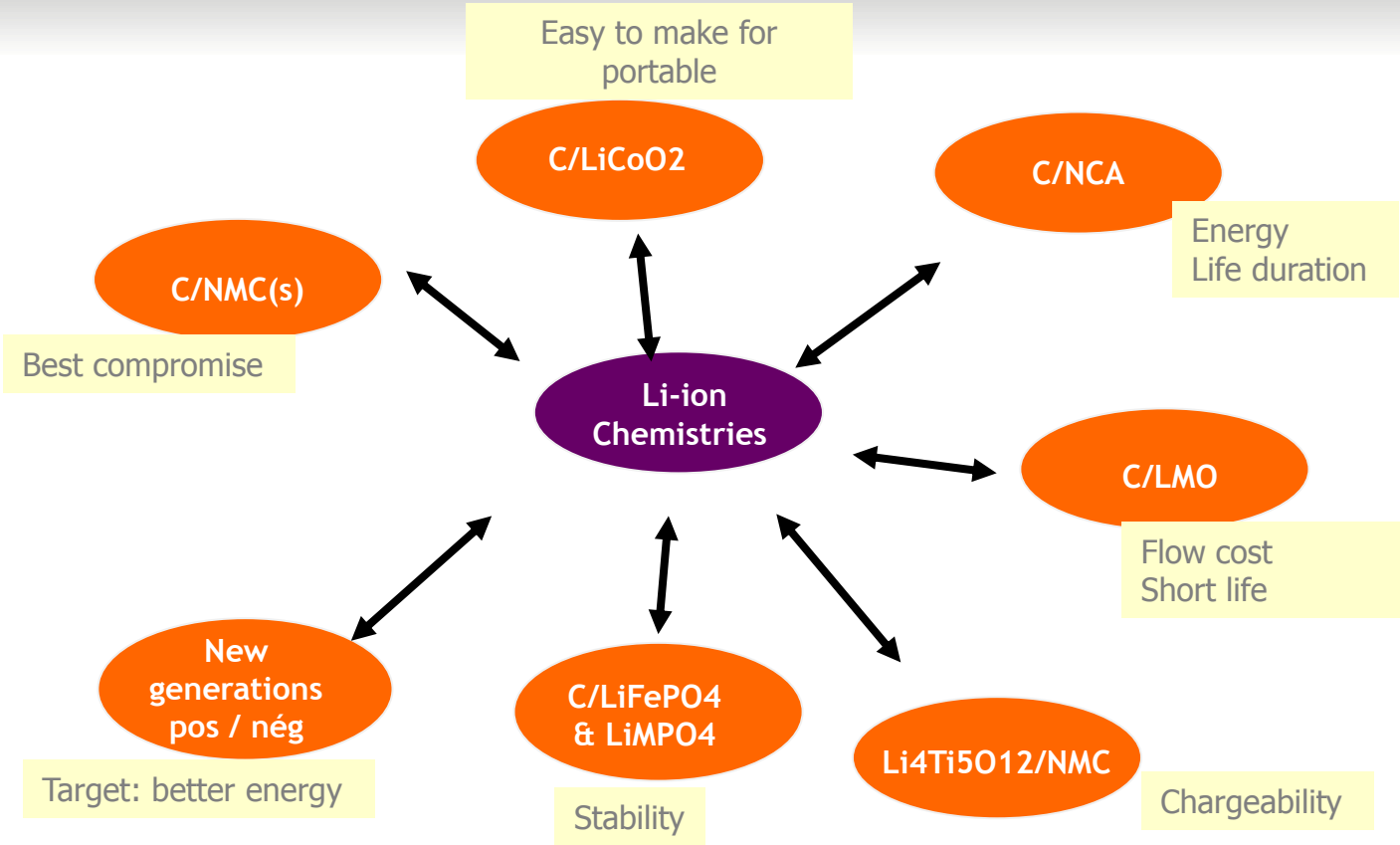
Source: Avicenne

Technology in evolution

- General trend: increase energy in same volume
  - PCB consumption reduces but quantity increases
- Specific Energy is at highest point at: **274 Wh/kg**
  - At cell level
  - Optimized for lap top, proposed by Matsushita Sanyo

- First cells new generation (Matsushita) with silicon in negative electrode
  - Announce 3 years ago
  - Small qty of Si : 2 – 3 %
- Li-ion will remain the first choice, with evolution and progresses in mass and processes

Sub-system Li-ion



Challenges to reach 300 Wh/kg

New generation pos & neg

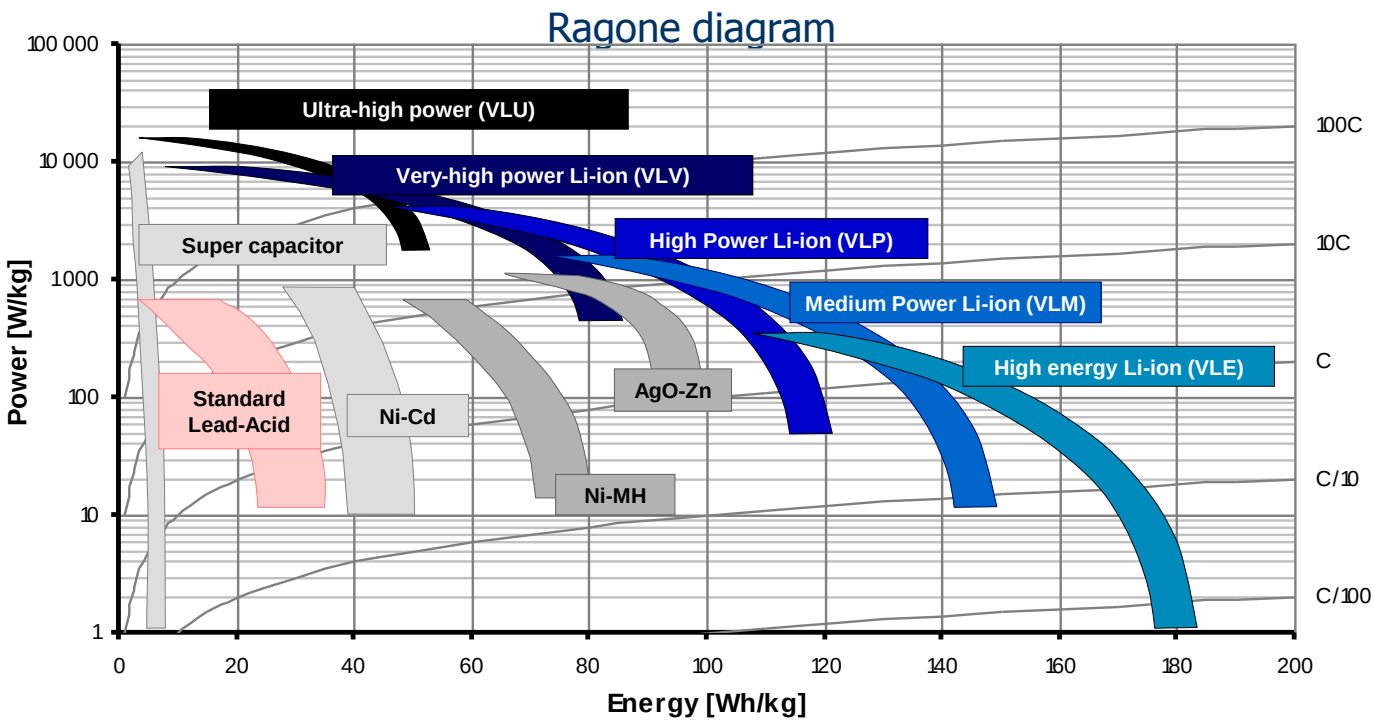
- Negative electrode based on silicium (composites, blends, oxides, nanostructures…)
  - 4000 mAh/g possible in theory
  - Life duration short (100 cycles) due to Si swelling
- NMC high energy (HE NMC) for positive electrode (Argonne patent) + 30% in energy but life duration and stability not resolved
- Other positive mass at high voltage (> 4 V) and high capacity (> 200 mAh/g)

Green mobility

Li-ion: main solution for EV/HEV

Type of vehicle	Type of battery	Energy range (kWh)	Car makers
Stop-and-start	Lead-acid w/wo supercapacitor	< 1	All
HEV	NiMH, High power Li-ion	1-2	Toyota (Prius)
PHEV	Mid power Li-ion	7-10	Mercedes
EV	High energy Li-ion	25-35	Renault/Nissan (Leaf, Zoé), Bolloré

Comparison for industrial batteries (cell level)



Road to electrifcation

- Stop-and-start
  - Low cost, cycling at low DoD: planned for most of new cars
  - L/A Batteries thanks to some improvement for cycling life

- HEV – PHEV
  - Introduction of Toyota Prius / battery Ni-MH 17 years ago!
  - 3 generation of vehicles and batteries, >1.5 million cars sold
  - Gradual improvement of Power/Energy ratio
  - New generation : Plug-in HEV with Li-ion batteries 4,4 kWh

- EV
  - Benchmark: 200 – 250 km autonomy ➔ Li-ion high energy
  - Specific Bolloré Blue car: Li-polymer, anode Li metal working at ~100°C ➔ good only for car sharing in cities

DoD: depth of discharge

Batteries of 2020 generation for cars

- Lithium-ion remains the main choice
- Optimization is different for "consumer" markets

  ➔ Technology of electrode is different

  - Increase of Energy is valuable for TCO is even more important
  - First target: reduce cost of Positive electrode (cobalt is too deer)
  - More simple BMS with mechanical structure

➔ LCO replaced by NMC or blending NMC / NCA / LMO

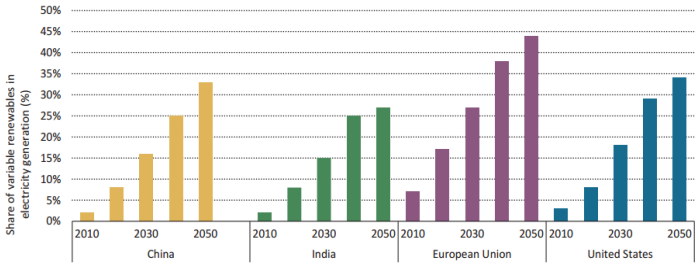
Stationary batteries

- Energy Storage for Renewable -

Storage requirement

- Renewable (EnR) expansion confirmed
  - Most of additional EnR are in Production
  - Most are Wind and PV
  - Up to 50% of mix in EU for 2050
- PV reach price parity
- Grids are saturated

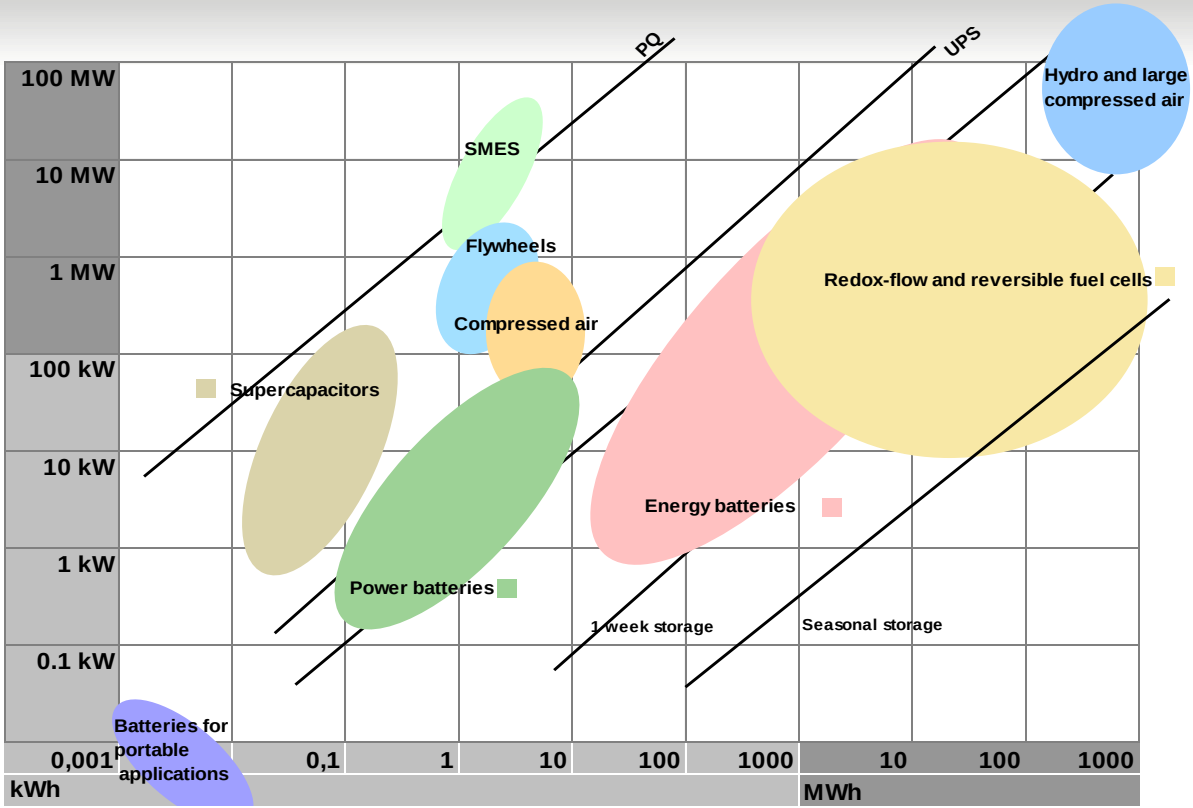
Figure 6: Share of electricity generated from variable renewables (%) by region in the 2DS



Source: IEA

EnR variables ➔ Need for more flexibility
➔ Need for grid support
➔ Need for local management of energy

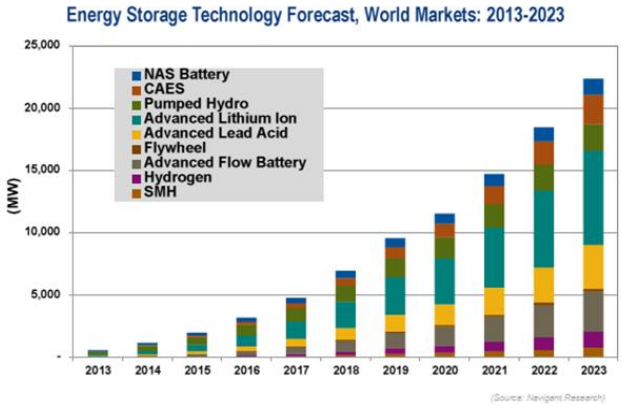
Various storage technologies

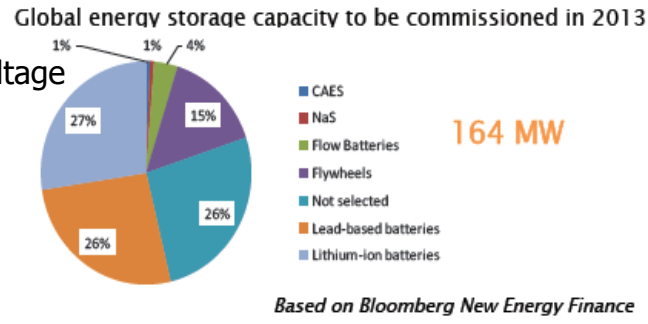


EC Document “Energy Storage : A key technology for decentralized power, power quality and clean transport” - 2001

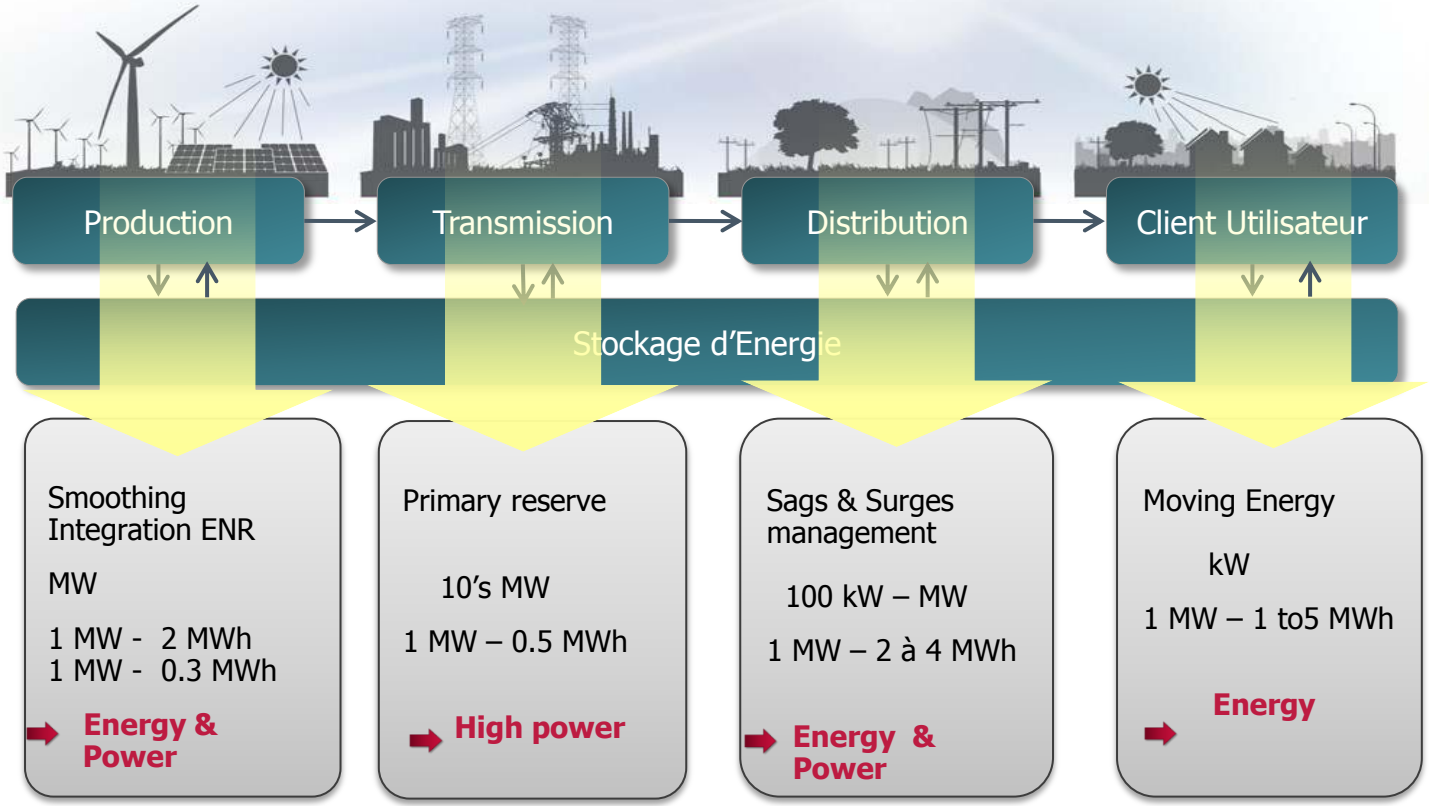
Where Li-ion would fit

- Battery growth
  - 50% of market (MW) is for batteries (Navigant, 2014)
  - …from which 60% are Li-ion
  - Higher growth for Li-ion
  - More than 30% of project are in Li-ion
- Small is beautiful
  - Few projects for mass storage
  - Limited potential for hydro
  - EnR = decentralized resource
    Most PV/Wind connected in low or medium voltage
  - Local storage of short duration (hours)
    have better potential short/medium term





Li-ion batteries well placed for all grid application



Different needs ➔ different solutions

- Different couples are used in front of optimum required
  - C- LFP security and power,
    SOC management complex and life duration at high temperature limited
  - C- NCA/NMC Excellent calendar and cycling life
  - LTO – NMC Very high power
    low energy density, cost / kWh high

- Optimization « Total Cost of Ownership » (TCO)
  - Capex & Opex vs. Life duration

- Technical challenges
  - Size and system complexity
  - Balance on charge / discharge
  - Cumulated Capacity / day very high : 4 to 6 C

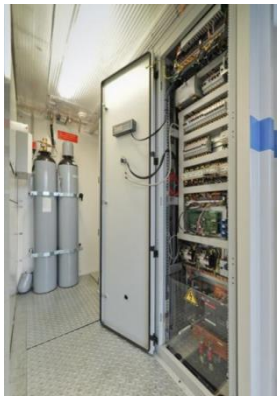
Complexity

Cells → Battery → Storage Unit → System

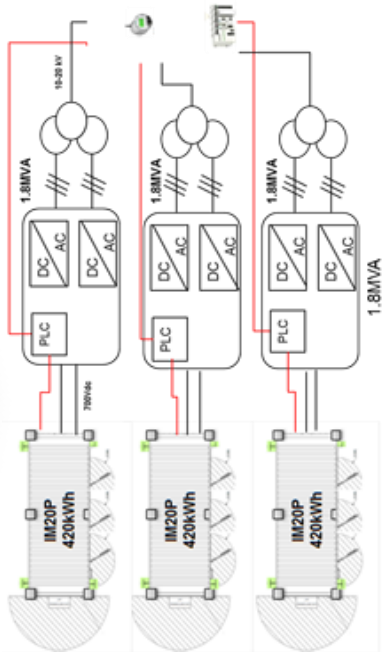
Module

Cabinet with modules & BMM

Container



Container with ancillary systems



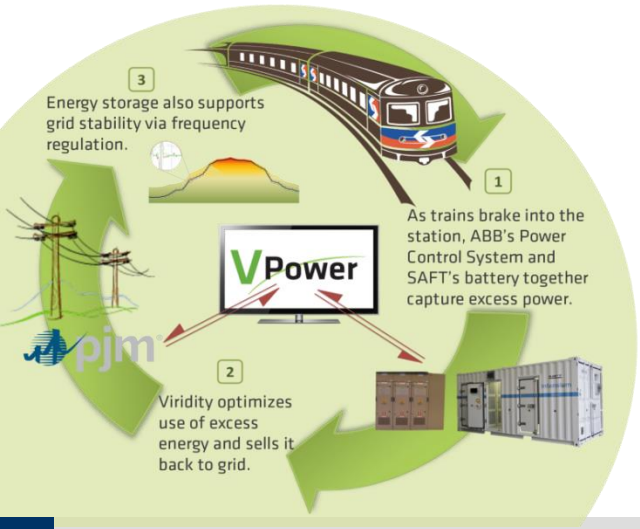
Storage, conversion, transfo, connect grid

Operational
February 2012

SEPTA – Philadelphia

Energy Storage, Regen, and Energy Markets…

…an Industry First



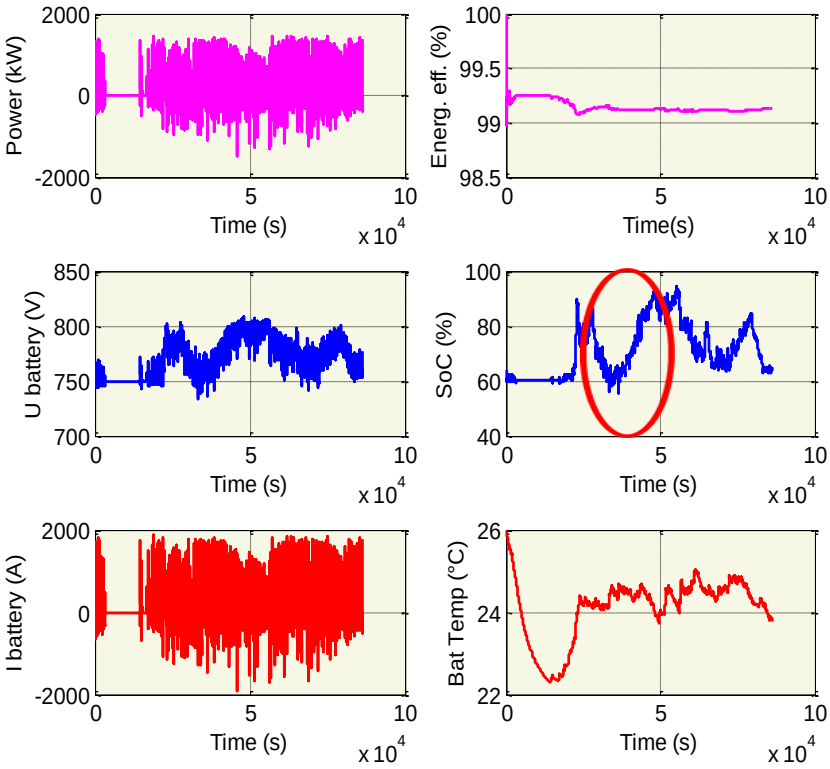
- Intensium Max 20P container
  1,5 MW - 400 kWh
- Partnering with Envitech (ABB)

- Customer: SEPTA
  - > Brake energy recovery from trains
  - > Injection during train acceleration
- Grid Services by Viridity to PJM
  - >Participation in frequency regulation markets

SEPTA – Philadelphia : SOC management

1 day operation (11/2012)

- Daily Energy turnover 2.2 MWh
- Average DOD 4%
- SOC management implemented
- Ageing 0.0055% per day



DOD – Depth of Discharge

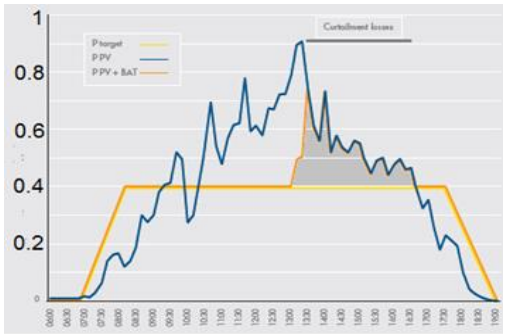
SOC – State of Charge

Installation
October 2014

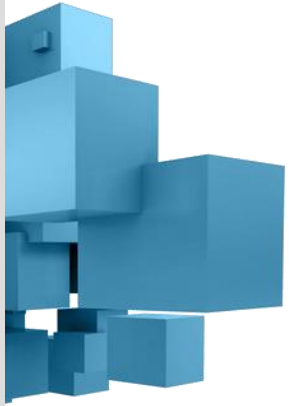
La Réunion – CRE Tender

- 9 MW PV PV plant
  - First project out of 16 contracts CRE (50MWp)
- 9 MWh Li-ion Energy Storage System
  - Consortium Saft, Ingeteam, Corex
  - 9 containers Intensium Max 20+E
  - 5,6 MVA converters in 4 containers
- Specification
  - Constant power injection @ 40% Pmax
  - Primary reserve : 10% Pmax / 15 minutes
  - Voltage support by PCS reactive power
- Battery Optimization

Energy capacity	Losses	Average DOD	Lifetime
9 MWh	11.3%	69.8%	>12 years
14 MWh	3.5%	56.3%	>17 years
21 MWh	0.7%	44.9%	>20 years



Salinas Solar Farm 10MWp, Puerto Rico



Negative materials
Exchanging more than electron per mole (Mg, Al)

Lithium air 1000 Wh/kg ?

Perspectives

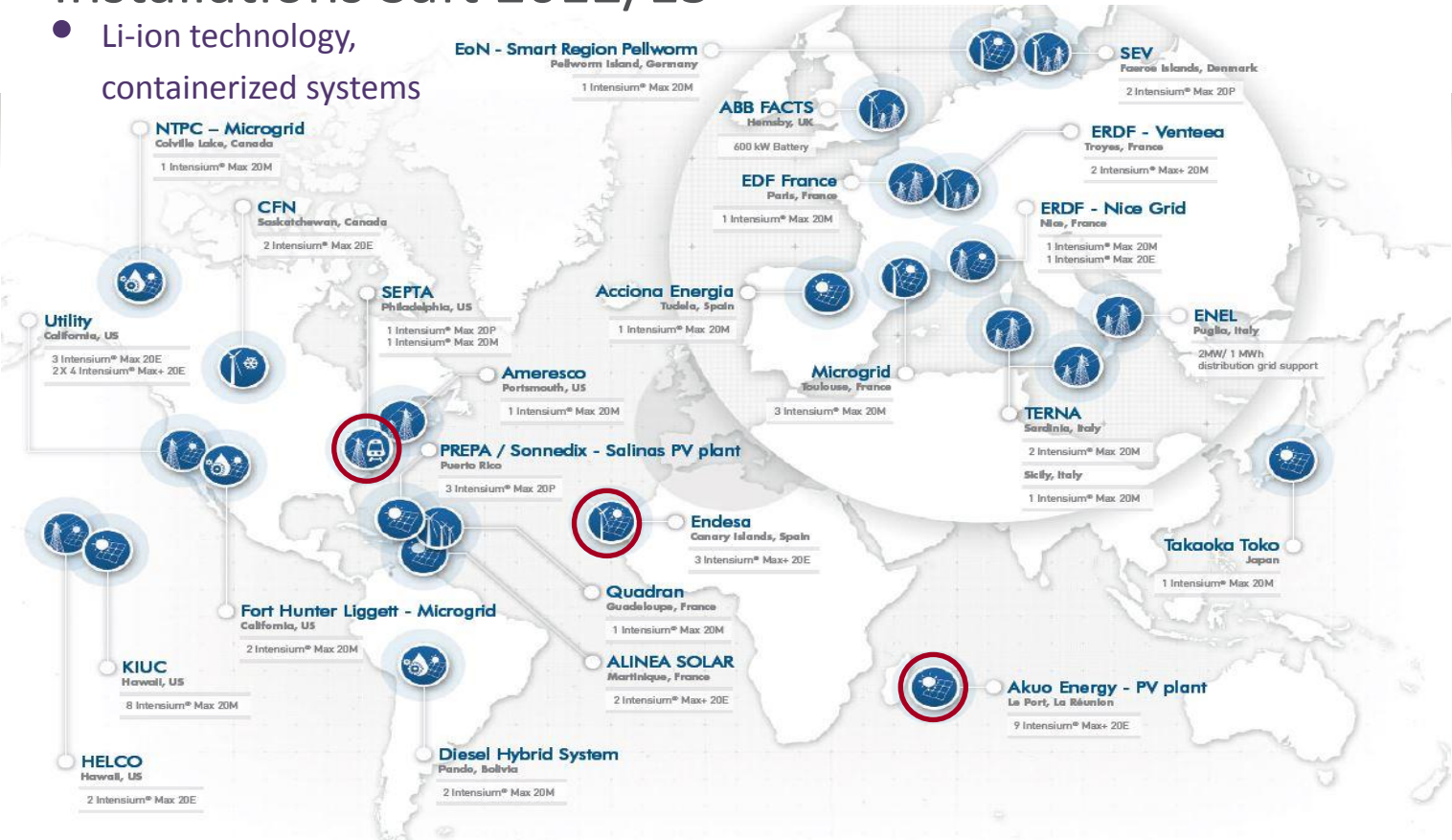
Lithium-sulfur
300 Wh/kg ?

Low cost sodium-ion batteries ?

Use of bio materials ?

Installations Saft 2012/15

- Li-ion technology, containerized systems



Merci

Vielen Dank

Dekuji

Terima Kasih

Thank you

谢谢

Tack

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