Energy storage with lead batteries: can they be cost effective?

Dr Geoffrey May
FOCUS Consulting

19th Asian Battery Conference
3-5 November 2021

FOCUS

Themes

- The need for energy storage with renewables
- Types of energy storage including batteries
- Battery types
- Key parameters for energy storage
- Sustainability – Lead battery recycling – Li-ion battery recycling
- Competitive position of lead-acid and Li-ion batteries
- Performance improvements for lead batteries

FOCUS

• Utility and Domestic Energy Storage

- Energy storage is essential for the effective use of wind and solar PV generation to reduce intermittency and time shift output
- Electricity suppliers have a duty to ensure the network is stable and resilient
- For domestic and small commercial consumers, feed-in tariffs have tended to reduce and self-consumption with storage is favoured
- Batteries are easy to install and attractive to energy storage with a large market for grid scale, commercial and domestic use

FOCUS

Energy storage applications

- At utility level:
  - To augment the spinning reserve of the network
  - To balance the network
  - To time shift energy delivery from renewable sources
  - To maintain system voltage
  - To maintain system frequency
  - For tariff management
  - To supplement power requirements to avoid network reinforcement
- At domestic and small commercial level:
  - For tariff management, self-consumption and energy security

FOCUS

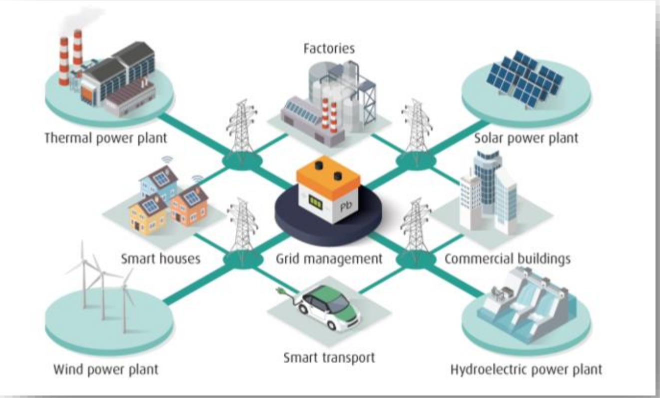
Energy storage technologies

- Mechanical Energy Storage
  - Pumped hydro, Compressed air energy storage, Flywheels

- Thermal Energy Storage
  - Heat energy, Cryogenic energy storage
- Electrical Energy Storage
  - Supercapacitors, Asymmetric supercapacitors,
  - Superconducting magnetic energy storage
- Chemical Energy Storage
  - Batteries: Lead-based, Li-ion, Na-S, Zn-air; Flow Batteries, VRB, Zn-Br, Zn-Fe
  - Fuel cells; water electrolysed and hydrogen as fuel, expensive, limited overall efficiency, more useful as gas to burn directly and distribute in existing gas networks

FOCUS

Position in Network for Battery Energy Storage



- Generators
- Transmission Services Operators (TSOs)
  - Main high voltage networks
  - Tend to use large energy storage systems – PHS – but also batteries
- Distribution Services Operators (DSOs)
  - Local electricity distribution at medium- to line-voltage
  - Battery energy storage being deployed
- Domestic and Commercial Premises
  - Battery energy storage being used with solar PV installations
  - Used for power quality (UPS) and for remote telecommunications

FOCUS

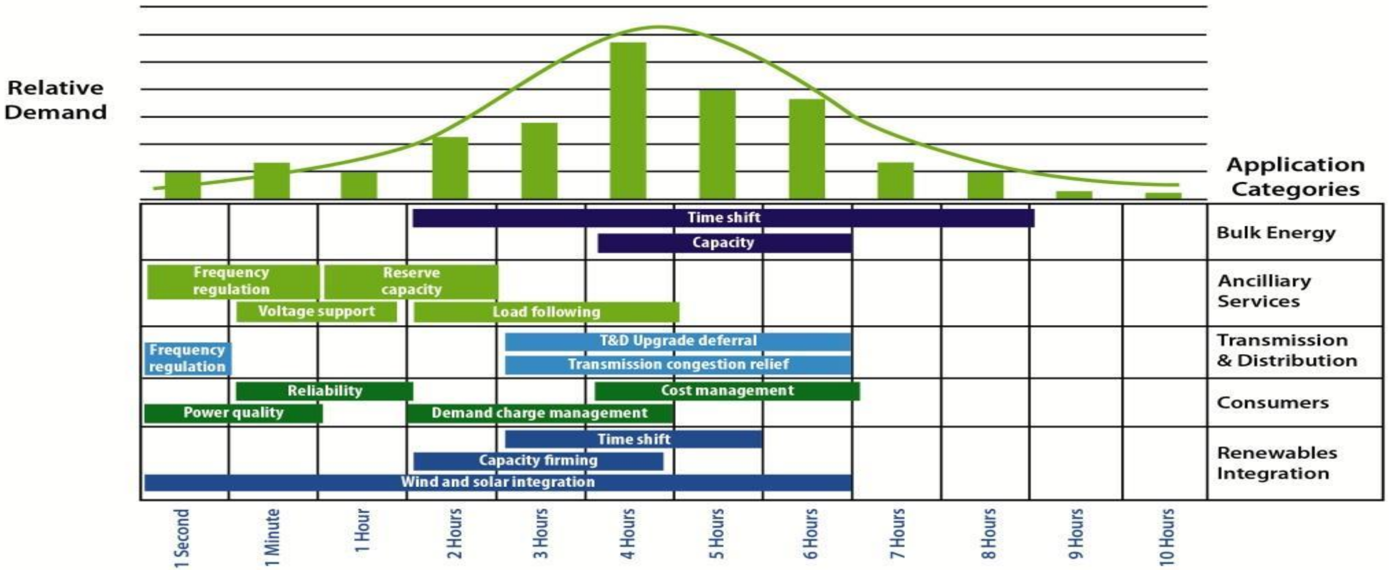
Energy Storage Applications

- Generators
  - Arbitrage, capacity firming, curtailment reduction
- Transmission Services Operators (TSOs)
  - Frequency and voltage control, investment deferral, curtailment reduction, black starting
- Distribution Services Operators (DSOs)
  - Voltage control, capacity support, curtailment reduction
- Domestic and Commercial Premises
  - Peak shaving, time of use cost management, power quality, off-grid supply
- Key Requirements
  - Short Term Operating Reserve and Fast Reserve

FOCUS

Energy Storage Markets

- Frequency regulation markets are limited
- The market will evolve to longer term storage which requires lower costs but opens a huge potential opportunity



FOCUS

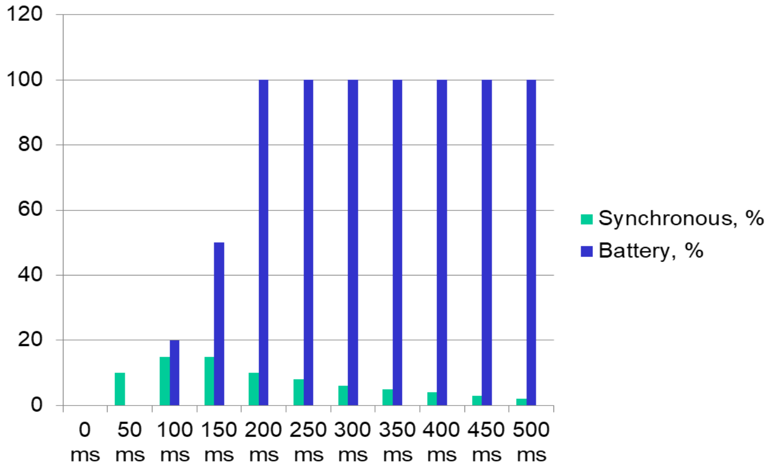
‘Digital Inertia’: Why batteries are better

- Synchronous Generators = Analogue Inertia
  - Rotating plant can respond in 50 ms to a sudden increase in demand with 5-15% increase in output but it falls rapidly and new capacity must be connected
- Batteries = Digital Inertia
  - Batteries can respond in 100 ms and deliver full power within 200 ms
  - More effective frequency regulation for longer times and the potential for longer term energy storage
  - Reduces curtailment
  - Ability to absorb as well as deliver power

FOCUS

Digital Inertia

- Spinning reserve is limited in time and energy
- Batteries can deliver power for longer times and at full rated output depending on installed capacity



FOCUS

Lead batteries: technical status

- Best in class offer up to 5000 cycles at 70% DoD
- Pasted plate, VRLA AGM construction with silica gel
- Nano-carbon additives to negative plates for more efficient charging and less sulfation especially in shallow cycle operation
- Thin pure lead plates offer higher performance
- Tubular plates also provide good cycle life batteries with anodes with combined with supercapacitors for improved shallow cycle performance

FOCUS

Energy storage systems

System	Life (Years)	Cycle life	Energy efficiency (%)	Installed cost, $/kWh
PHS	50	20000	80	250-350
CAES	25	10000	65	200-250
Lead	15	5000	85	400-600
Li-ion	15	5000	90	800-1000
Na-S	10	4000	80	600-800
VRB	15	6000	70	750-850
$Zn-Br_2$	10	4000	70	600-800
Zn-air	15	5000	80	300-350

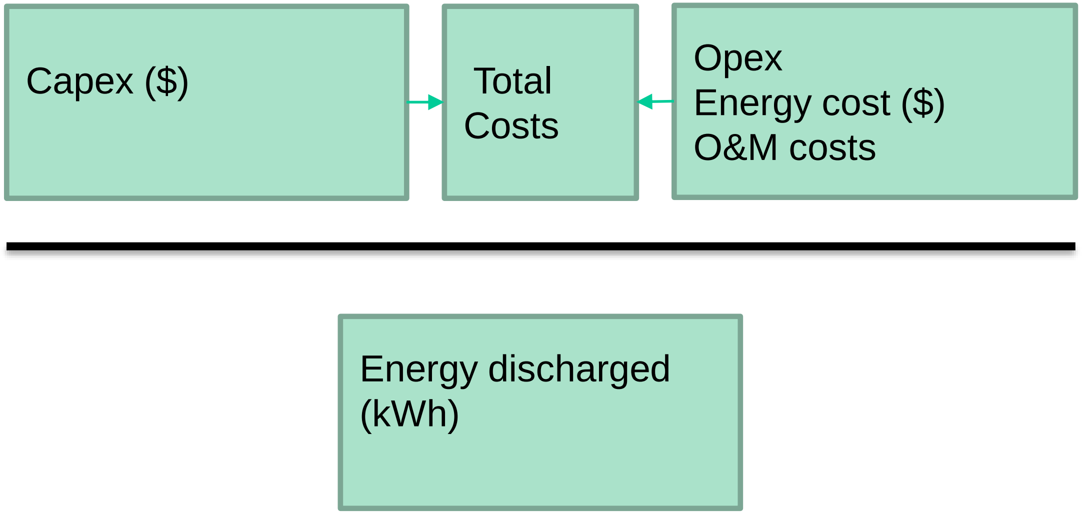
FOCUS

Competitive position of Lead and Li-ion batteries

System	Lead	Li-ion
Energy density	35-40 Wh/kg, 80-90 Wh/l	160-180 Wh/kg, 300-350 Wh/l
Power density	250 W/kg, 500 W/l	1200 W/kg, 1200 W/l
High temperature performance	to 40°C	to 50°C
Low temperature performance	to -30°C	to -20°C
Charge acceptance	Good	Better
Cycle life	1500-5000	1000-5000
Overall service life	up to 15 years	10+ years
Reliability	Proven	Needs to be assessed long term
Sustainablity	Excellent	Recovery methods in development
Safety	Good	Issues to be addressed
Cost at battery level	$150-200/kWh	$600-$800/kWh

FOCUS

Levelized Cost of Storage (LCOS)



LCOS is expressed in $/kWh (Σ$costs/kWh) and takes account of the overall asset life using discount factors. LCOE is used by utilities to assess the breakeven figure for an investment.

FOCUS

Challenges for technical development of lead batteries for ESS

- Cycle life is the key – best in class can achieve 5000 cycles at 70% DoD
- Shallow cycle life is important for many applications and carbon additives to the negative plate are important
- Alloy development to reduce corrosion will allow thinner plates to deliver higher energy and power density
- Battery management with controlled charging is essential
- Sustainability and safety are keys for lead batteries
- Lead batteries can achieve an LCOS that is competitive with Li-ion batteries depending on application

Energy storage in Europe

- Energy storage market grew to 1.7 GWh in 2020 but is forecast to increase to 3.0 GWh in 2021 (excludes PHS) with an installed base forecast of 8.3 GWh by the end of 2021 – up from 0.6 GWh five years ago
- 2020 was impacted by COVID-19 – residential markets were reduced as installers were unable to access premises
- Commercial and industrial markets more severely – commercial customers cancelled or delayed projects and this will continue until businesses are on a sounder footing
- Front of meter projects were less affected with ancillary services providing strong growth, particularly in the UK and Germany but with investment also in France, Nordic countries, Ireland and in Eastern Europe
- The majority of battery projects are Li-ion especially for ancillary services

Safety

All batteries are self-contained energy sources and can go into thermal runaway under fault conditions

- Lead batteries
  - Lead-based batteries have lower energy densities than Li-ion batteries and have a lower risk if abused
  - Lead-based batteries have aqueous electrolytes which are not flammable, use flame retardant containers and covers and have flame arresting vents to avoid external ignition of hydrogen being a hazard
- Li-ion batteries
  - Li-ion batteries have flammable organic electrolytes and highly reactive active materials
  - Li-ion batteries are equipped with safety vents to prevent explosion and there are well developed safety tests
  - Accidents are rare but more prevalent with Li-ion with greater risks

FOCUS

Li-ion ESS battery fire in S Korea

FOCUS

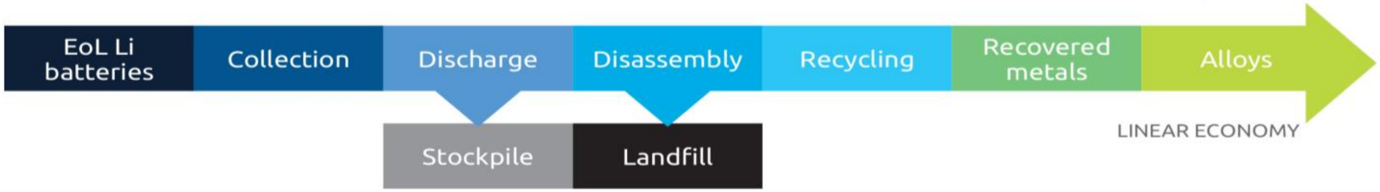
Sustainability – lead batteries

- Lead is the most efficiently recycled commodity metal
- Batteries contain ~65% by weight of lead which is fully recoverable at end-of-life
- 99% of end-of-life batteries are recycled
- Containers and covers are also recycled
- Acid may be recovered and converted to sodium sulphate
- The recycling industry operates without subsidy in full compliance with environmental regulations
- For a lead cost of $2,200/te, a credit of ~$600/te is available to the user at end-of-life

FOCUS

Sustainability – Li-ion batteries

- Legislation requires batteries to be recycled at end-of-life
- At present most Li-ion batteries reaching end-of-life are consumer batteries from portable electronics
- Most have cathodes with a high cobalt content which has an economic value
- Battery processors charge a fee and then offer a credit if there are materials of value
- For energy storage batteries, these will have smaller or zero Co content and have less, if any, value
- Processing costs for Li-ion batteries are estimated at $3,000-$5,000 per tonne with limited recovery of materials for re-use



FOCUS

Conclusions

- Lead batteries are the most widely used rechargeable system
- Lead battery sales were $38BN in 2019, Li-ion battery sales $45BN but by MWh lead batteries represent 75% of worldwide battery production
- The lead battery industry is well established worldwide with technically capable producers with many years of experience
- Lead batteries are continuing to be developed as application requirements evolve and particularly for energy storage
- Lead batteries are cost competitive with Li-ion batteries for energy storage both at grid scale and for domestic installation
- Lead batteries are safe in operation
- Lead batteries are fully sustainable; Li-ion batteries are not

Questions…

Dr Geoffrey May
FOCUS Consulting
Tel: +44 1509 890547
Mob: +44 772 069 6321
E-mail: g.j.may@btinternet.com
Web: www.focusbatteryconsulting.com

FOCUS