

# How to transform innovative battery opportunities in field operational solutions for Telecom/IT

Didier Marquet, Brian Françoise\*, Olivier Foucault, Samuli Vaija, Eric Philipot,  
Orange / Technology Global Innovation (\*Sofrecom)

Claude Campion  
3C Projects France

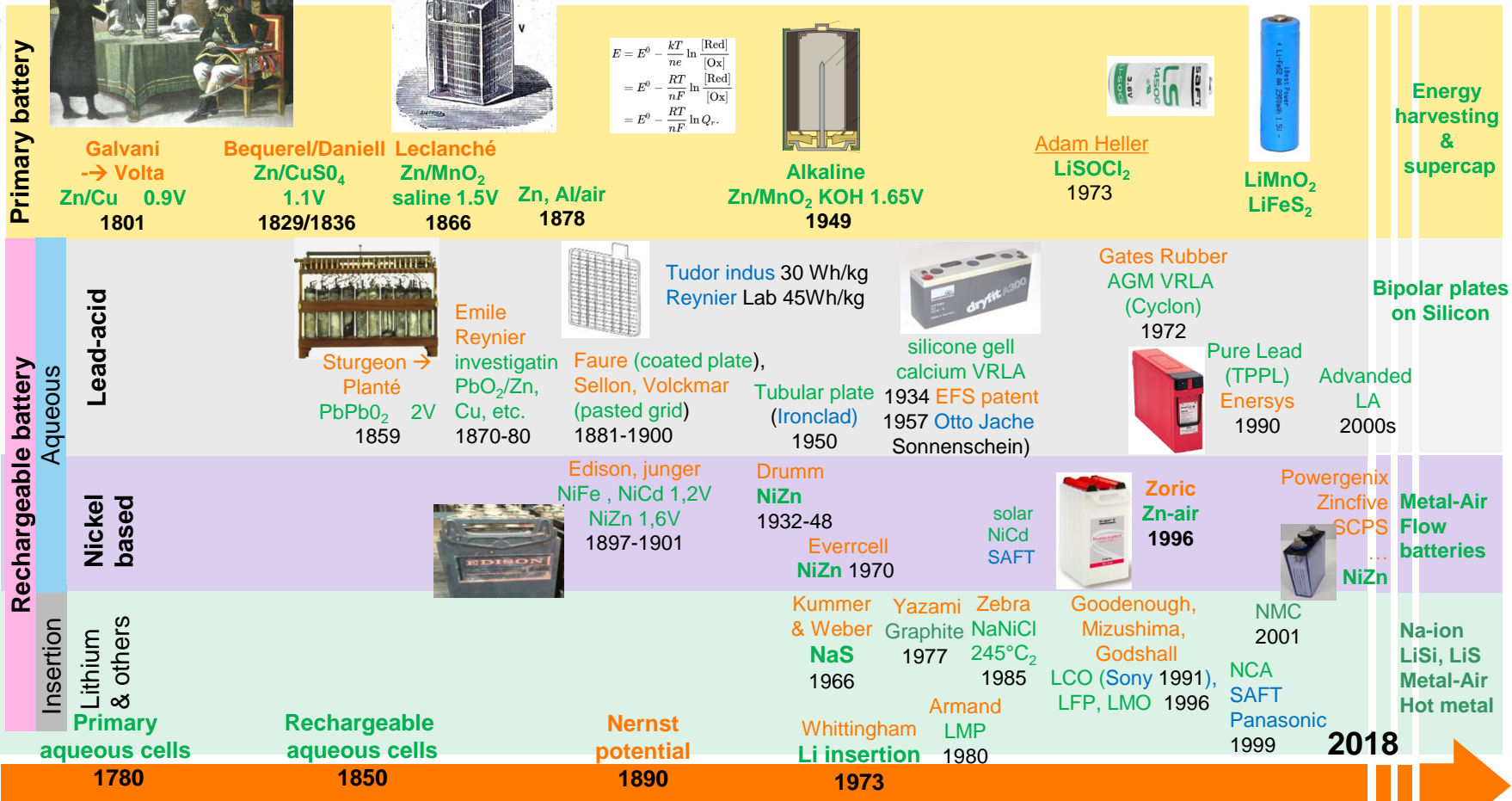
# ACKNOWLEDGMENTS



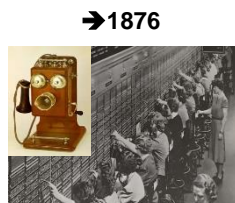
- The French Ministry of Industry and Commerce (DGCIS) is thanked for funding part of this work in the European project SOOGREEN labelled by Celtic-Plus: research on Li-ion batteries with adapted O&M for stationary ICT applications in hot temperature and deep cycling on smart grid and renewable energy.
- Orange colleagues of skill centers, countries experts involved in battery solutions engineering or (O&M), environmental experts and buyers are also thanked for their valuable inputs used in this paper.

# More than 150 years of batteries & Telecom history

orange™



Morse telegraph



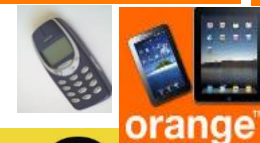
Phone



Radio/TSF



Batteries installed  
in telecom site (phone, XDSL, ....)



5G  
orange™

# Evolution of batteries in IT Network

orange™

## Increasing Telco/IT (HD video, data, IoT, ...) stresses green battery requirements:

- demands-response & REN self-consumption → more cycles than back-up
- Telecom development on bad grid or offgrid imposes cycling and hot operation:  
10 000's Orange off-grid radio BS (PV + vented tubular OPzS LA, hybrid Diesel, HGB, ...)

## 1970 Orange centralized power:

- vented Lead-acid 48VDC of kAh's batteries with lot of maintenance,
- 1000 CO (10 hours batt. autonomy + 2 Diesel) , 15.000 access sites (12-36h battery)

## 1980 -1995 Orange distributed AC/DC CNET\*<sup>1</sup> (Orange) + industry & research:

- smart  $\mu$ P management + modular HF rectifiers +VRLA blocks enables shorter autonomy: 1 Diesel + ¼ h battery in big CO and 4-16 h in small CO
- distributed AC/DC reduces installation by 10 (5t copper → 500kg for a 50 kW room).
- very low maintenance with AGM VRLA

**E2000–E2005: back to centralized 48V in big CO:** lower cost with high density rectifiers  
**Reduced Battery weight issues and maintenance** at floor level **but back to 48V cable over-costs**  
**and still 48V batteries and server UPS batteries maintenance**

## 2017: centralized ETSI\*<sup>2</sup> and ITU-T\*<sup>3</sup> 400VDC solutions: low cost 400V distribution

- one 400 VDC battery (no UPS) + easy modular O&M and recycling
- 200-400VDC: FTTx, 5G remote powering (3) → access sites without battery

2018 installed batteries estimation : > 95% Lead-Acid

Orange ~ 2.4 GWh (60% on-grid fix+mobile+datacenters + 40% offgrid PV+HGB) NTT~ 2 GWh  
→ World Telecom stationary battery : ~ 75 GWh (extrapolation) ~10 B€

\*<sup>1</sup> CNET : National Telecom Research Center, now Orange Labs

\*<sup>2</sup> ETSI EE EN 300 132-3, ITU-T L.1200 series

\*<sup>3</sup> ETSI EE EN 302 099



# Review of battery evaluation in Orange 1/7



## Regenerative Metal-Air 1985-90 tests

- **Zn /air (SORAPEC):** power & capacity ok, Zinc plated over plastic pellet fuel easy to load, but self discharge and solid carbonates troubling operation...
- **Al alloy-air (Chloride Alupower):** power & capacity ok with anti-passivation alloy, but same issues of carbonates + Al hydroxide gel troubles for the regeneration process, ...



## Metal-air batteries are promising but improvements are required:

- High energy 150 to 400 Wh/kg, but slow discharge (> 5-10 h)
- Periodic flow of KOH on Air electrodes avoids drying, but metal corrosion  
→ self-discharge, carbonates blocking air and liquid circulation, CO2 filters maintenance.
- Need research to reduce or substitute Platinum catalyzer in air electrode
- Efficiency limited by current leakage between inter-cells voltages → 48V limitation
- Electrolyte or electrodes/fuel regeneration issues
- Many recent works: EdF+ SCPS then ZNR/Zinium, EoS, NantEnergy, ...

About the same issues applies to flow batteries and fuel cells !



# Review of battery evaluation in Orange 2/7



## Improvement of AGM VRLA battery management

- End 80's reducing floating corrosion by intermittent charge on GEODE:

*Each Redundant battery put weekly in open circuit by opening relay and then charged without overcharge to compensate self-discharge and avoid sulfating.*

→ No bad effect on battery but trial stopped due to relay failure.

- Other 2000's Orange Lab trials

- restart of intermittent charge versus floating: collaborative work with LA battery manufacturer on new VRLA design. Accelerated tests by temperature cycles

→ improved lifetime and efficiency, but trial stopped due to thermal issues on plastic.

- State of health determination (impedance measurement and other tests)

→ in floating, best solution: partial discharge test + block U, Istring measurements.

## Advanced LA Batteries, still strong competition with Lithium

Grid storage (ESS), hot cyclo-loading on bad grid or PV, or deep hot cycling HGB.

- pure AGM VRLA used since Planté but not after because it was too smooth for handling.

With robotization it is back now for fast hot cycling in HGB.

- PbC VRLA: old solution of carbon in active Material. good power (car start&go). Lot of cycles but carbon oxydation → water consumption? → it needs special charger

→ Both accept Partial Charge, fast & hot recharge competing with Lithium batteries.

- Cristal Silicon VRLA: use lower density acid, specific alloy and active material complex, accept PSoC, full discharge, very low self-discharge at high temperature BUT expensive

→ need more evaluations & tests

- Bipolar LA on Silicium: to be followed



# Review of battery evaluation in Orange 3/7



## NiCd

High and reliable performances even at extreme temperatures but expensive.

New floating NiCd batteries do not require water refilling as VRLA, and Solar NiCd requires less water refilling (> 12 months) compared to OpZS LA (3-4 months)

→ Orange tests NiCd battery in 1 kW solar mobile station in hot Senegal.

**NiCd has not been impacted by over discharge due to 12 month delivery delay.**

**Good behaviour, low maintenance**

## MiMH

Test done with success on small size cylindrical NiMH + PV on IoT device. New less expensive MH proposed for Telecom mast mobile Back-up. **Extreme temperature, reliable, about no BMS**

→ **It needs more evaluations & tests**

## NiZn

**Orange tests of 10 Ah SCPS 1.65V cells and 12V blocks samples have shown:**

- no dendrites issues
- 2h fast cycling (12 per day) : **1000 cells cycles at 100% DoD at 35°C** (capa loss: 30%)
- 12V PV cycling test: **500 cycles at 80% DoD at 30°C without BMS** (loss: 20%).
- **Maybe no BMS as niMH.**
- **power to start Diesel with few Ah at low temperature**
- self discharge and floating have not been tested.
- **cost between good VRLA and LFP**

→ **waiting for new big manufacturer pre-industrial cells for further tests in 2019**



# Review of Lithium battery evaluation in Orange 4/7



**Not operable**  
because  
**no BMS\*** or **not adapted**

**Preheating required**  
→ Impact on efficiency  
→ Too high fire risk

## A Lab and field tests on 48V LiB modules

In **Orange Cote d'Ivoire** for back-up of curb telecom cabinet with high internal temperature and not sufficient volume for VRLA.

**Orange Lab test** on the early supplier of **48 V 4 kWh Li-NCA modules**:

**3% capacity loss after 1000 cycles at 30% DoD at 35-40°C.**

- **BMS gives lot of data**, but **complex interoperability**
- No short-circuit test was done to avoid BMS electronic failure

**Orange Test** started on LFP 19p 48 V racks (50-200 Ah) at 35 to 40°C.



\* BMU, BMS: Battery Management Unit or System



# Review of Lithium battery evaluation in Orange 5/7

## B) Soogreen EU project (1)



**SoogreenTarget:** smart grid or offgrid green energy services using Telecom power system

**Battery Task :** select the best non lead battery based on O&M, maturity and cost criteria

**LFP technology selected considering high safety, good cycling performance at 35-45°C and tolerance of higher temperature + LFP does not use Cobalt (Cost + environmental aspect)**

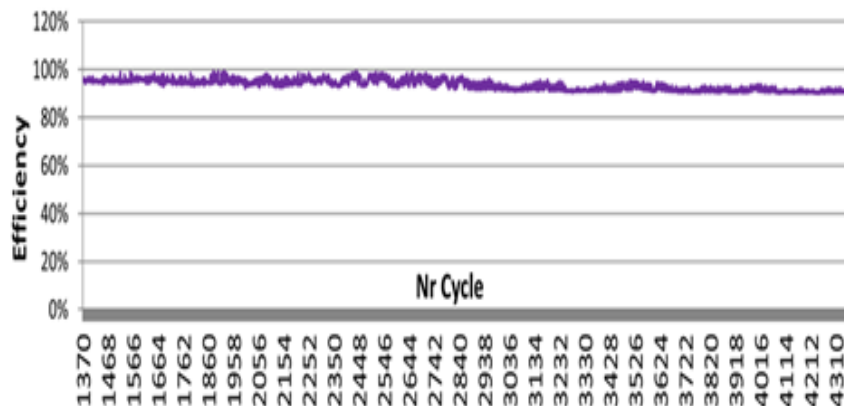
→ verified by our tests on 8, 60, 90 Ah LFP

**1<sup>st</sup> tests achieved on some prismatic cells of 8Ah nominal capacity :**

- Efficiency > 90% after 4300 cycles @ 100%DoD at 0.4C rate
- Capacity loss is linear without sudden death

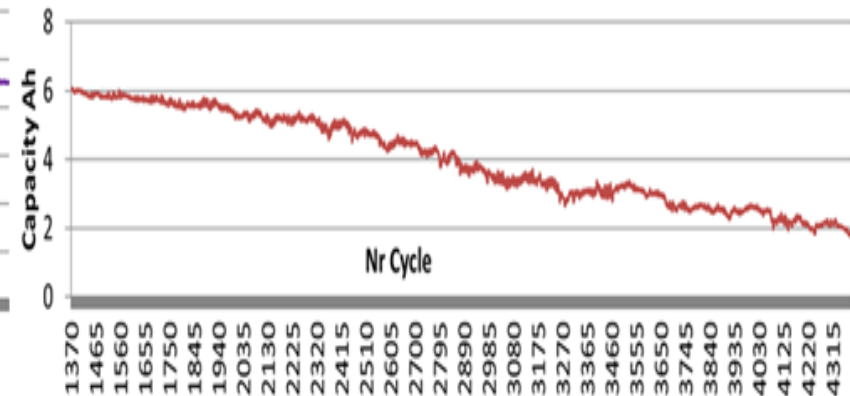
LFP 8 Ah Cell Nr 4 - Efficiency (U min 3,00 V ; U Max 3,55 V)

— Efficiency



LFP 8 Ah Cell Nr 4 - Capacity (U min 3,00 V ; U Max 3,55 V)

— Capacity

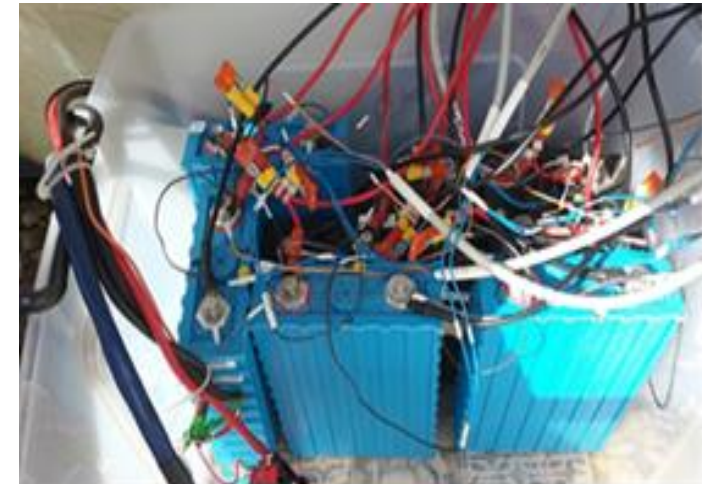
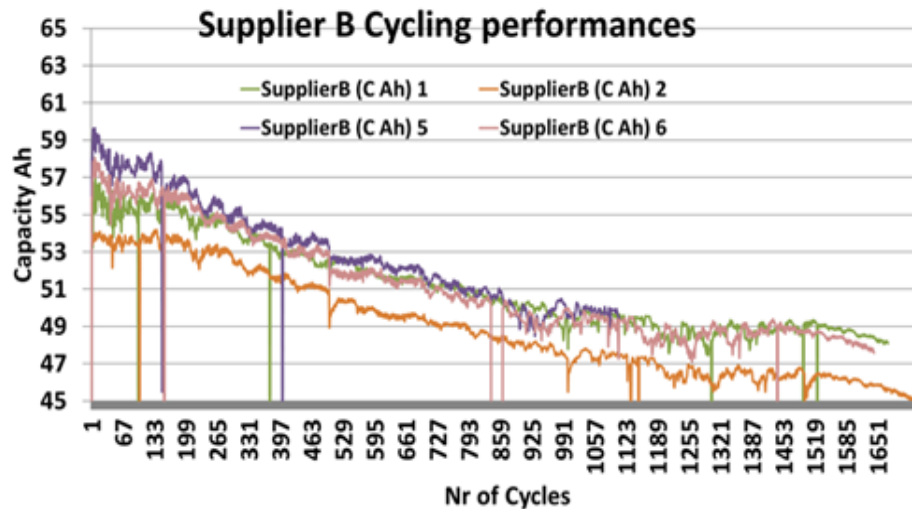


# Review of battery evaluation in Orange 6/7

## Soogreen tests (2)



2<sup>nd</sup> test achieved on some prismatic cells of 60Ah nominal capacity:



- ☺ High cycling with 4 suppliers, **>1500 cycles @100% DoD, C/3 rate, 16% capacity Linear Loss** voltage and charging modes setting are essential
- ☺ **Energy efficiency >96%**
- ☺ **Partial state of charge acceptance**
- ☺ Endothermic charge at 0.3C rate (-1°C to -5°C). → good in hot climate
- ☹ At 50°C, **no thermal runaway** without voltage setting mandatory for Lead-acid (accelerated ageing)
- ☹ **Capacity dispersion between cells**

At 1000 cycles, a rest time of 15 min has been added between charge and discharge  
→ capacity decrease was stopped but effect need to be clearly quantified

# Review of battery evaluation in Orange 7/7

## Soogreen: BMS specification/lab simulation 3

orange™

### BMS Orange lab simulator

- “active” (non-dissipative) high current balancing in charge/discharge mode on a 12V 90Ah battery (4 LFP cells)
- Cell voltage accurately balanced with a step-down converter.



### Test 1: partial battery I-mode charge

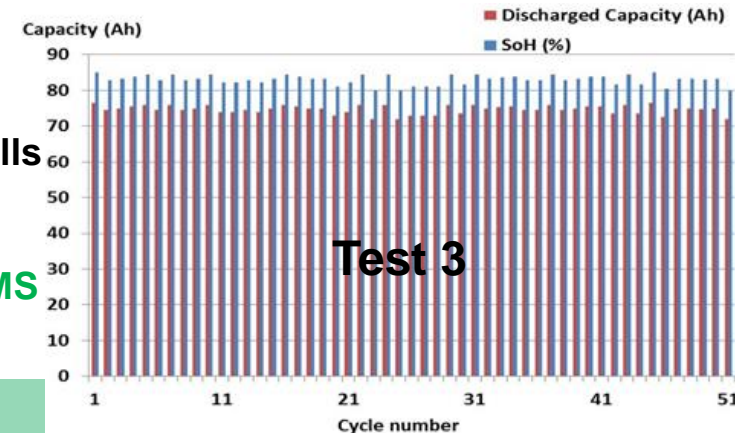
- Results : **Battery capacity stabilized at 81Ah**

### Test 2: same + each cell U mode charge

- Results : **capacity stabilized at 86Ah (97,7% nominal)**

### Test 3: same balancing on a dispersed battery (3 good cells 87 Ah, 1 weak cell 63Ah)

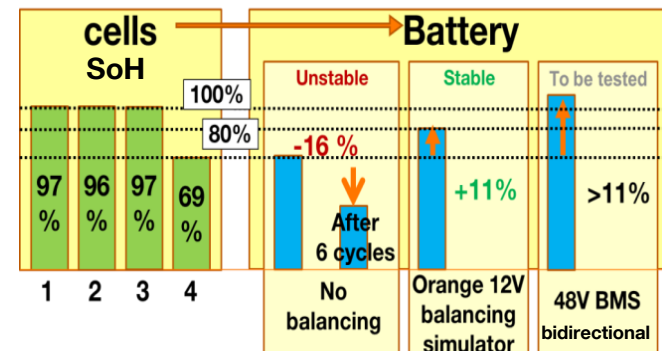
- A legacy BMS limits capacity to 63Ah
- Results : **capacity 72Ah (80% nominal) thanks to our BMS**



→ The high current balancing maintains performance and gives time to predict failure and repair.

Lab test on a small 8 Ah 4 cells LFP battery has shown that **a bi-directional balancing would improve battery SoH & global energy efficiency, and reduce the charging time.**

Not tested on 90Ah as bi-directional converter not available.

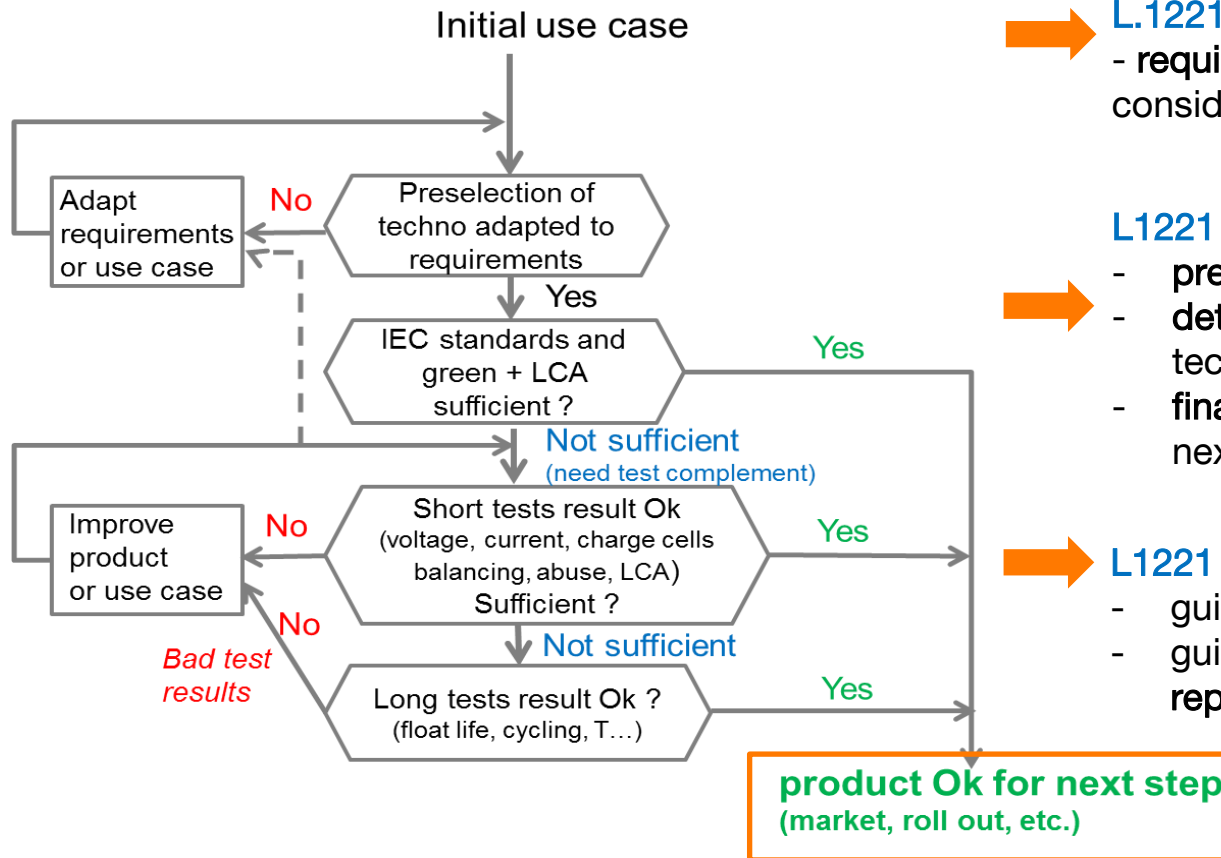


# New ITU-T & ETSI standards on Energy Storage

ITU-T Recommendation L.1220 series equivalent to  
ETSI Standard TS 103 553 series



## L.1220 Innovative storage and iterative selection method chart overview:



➔ **L.1221 Specification step:**  
- requirements expression for each considered applications

➔ **L1221 Matching step**  
- preselection of technologies  
- detailed scoring of each technology regarding spec  
- final discussion detailed in next slide

➔ **L1221 Optional tests step**  
- guide of test definition  
- guide of test method and reporting



# Using standards: pre-selecting HGB battery



## Advanced LA batteries: lower cost and medium performance

Pure lead thin plate AGM VRLA (TPPL) used as reference for HGB, high recharge rate, operation at 45°C, no maintenance, cycling lifetime 3 to 6 years, <150 €/kWh.

Issue of Theft for Lead as easy to reuse or melt for lead resell → GPS trackers ?

Lead-Carbon batteries: better PSoC, high cycling but water consumption above 35°C: specific charge ?

## Hot battery 245°C NaNiCl<sub>2</sub> : no effect of MEA temperature

Initially for EV (80 Wh/kg & 80 Wh/l) before Lithium, new marketing on hot cycling use, good cycling lifetime 8-12 years (5000 cycles at 60% DoD)

but medium efficiency: chemical 85%, but system 74% due to heating,

But slow charge and discharge (3h at 50% DoD) oversize the battery

Very few thermal cycles, so maintenance shall be faster than 2 days to avoid 10-24h cold start

→ Capex about 4 times higher than Lead-acid financial and lifetime risk.

## Li-Ion batteries

High cycling at high DoD 5000 cycles at 50 % DoD (future LTO 10 000 cycles).

High efficiency > 90%, PSoC, low self-discharge allows long shelf period.

Risks on BMS reliability and communication with the charging system → technician training

TCO not always optimal compared to LA batteries due to high initial costs.

Fast techno change due to cobalt and rare metal cost metal may get decision makers afraid

## Nickel technologies

NiCd: cadmium management at end of life is an issue in MEA

NiMH: very performing but maybe too expensive

NiFe: efficiency, water consumption and cost needs evaluation

NiZn: fast and hot cycling lifetime, medium cost, no theft, not yet available, maybe in 2019



# Environmental impact and circular economy



**Batteries environmental footprint issue is raw material supply more than reserve.**

Material	Mt / year (mines/total)	reserve (Mt)	Used in batteries	Year
Lead	4.8/11.6	88 to 100	71%	2016
Lithium	0.035	8 to 14	39%	2016
Graphite	1.2	215 to 250	8%	2016
Nickel	2.25	78 to 100	7%	2016

- **European Commission identify Critical Raw Materials list (EU CRML) as :**

- production concentrated in a handful of countries
- end-of-life recycling input rate about null.

Main risk is political: worldwide governance, policy perception and human development

- **11 supply risk indicators on future technology demand or substitutability.**

## Examples:

- **LA battery:** antimony of cycling vented lead-acid comes at 87% from China and is poorly recycled (28%) but 162 kt are produced for 3.4 Mt estimated reserves

- **Lithium battery materials:**

- Cobalt is mainly extracted in RDC as a by-product of Copper or Nickel and cost is highly increasing up to 95 \$/t in 2018 but reserve are estimated to 65 years.
- Graphite comes from China but may be produced artificially from carbon. Cost can be an issue
- **NiMH or LFP:** Ytterbium comes mainly from China but reserves were estimated to about 1 Mt.

**It needs further study on Life Cycle Analysis study for batteries selection, as many have divergent results e.g. for comparing Lead and Lithium Batteries**



# CONCLUSION AND NEXT STEPS



**Battery market and performance requirements increasing** with ICT services development (big data, media, IoT) and offgrid customers or resilient uses.

**Lead-Acid batteries still dominating** for more than 1 century (lower cost, good performance, lifetime, easy O&M and recycling)

**Orange tests and Soogreen Eu project point out opportunity** for replacing lead or intensive hot cycling on bad grid or offgrid or resilience use.

Lithium LFP is one of the best tradeoff for safety, performance and limited use of critical materials (cobalt, rare earth to be saved for portable device and EV high energy density batteries).

Conditions for Lead- acid replacement are **same easy O&M** by cell or block replacement ability and **high current BMS for Lithium** fast commissioning and no limitation by cells dispersion.

The **new ITU-T and ETSI standard on battery evaluation method** should simplify and accelerate the battery selection process.

**New possible challengers of Lithium** are advanced Lead (PbC, ...), NiMH, hot sodium or NiZn batteries when field performance and TCO will be better in tests.

**Intensive research on energy storage for smart renewable energy:** the list is open with Metal-air, redox flow batteries, salt batteries ... if fitting ICT applications.

**Thank you,  
Gratie,  
Domo Arigato,  
Merci,**

**...**

**Any questions ?**