



Advanced Rechargeable Batteries

The Lithium-Ion Battery

Service Life Parameters

Geneva
May, 2013
UN

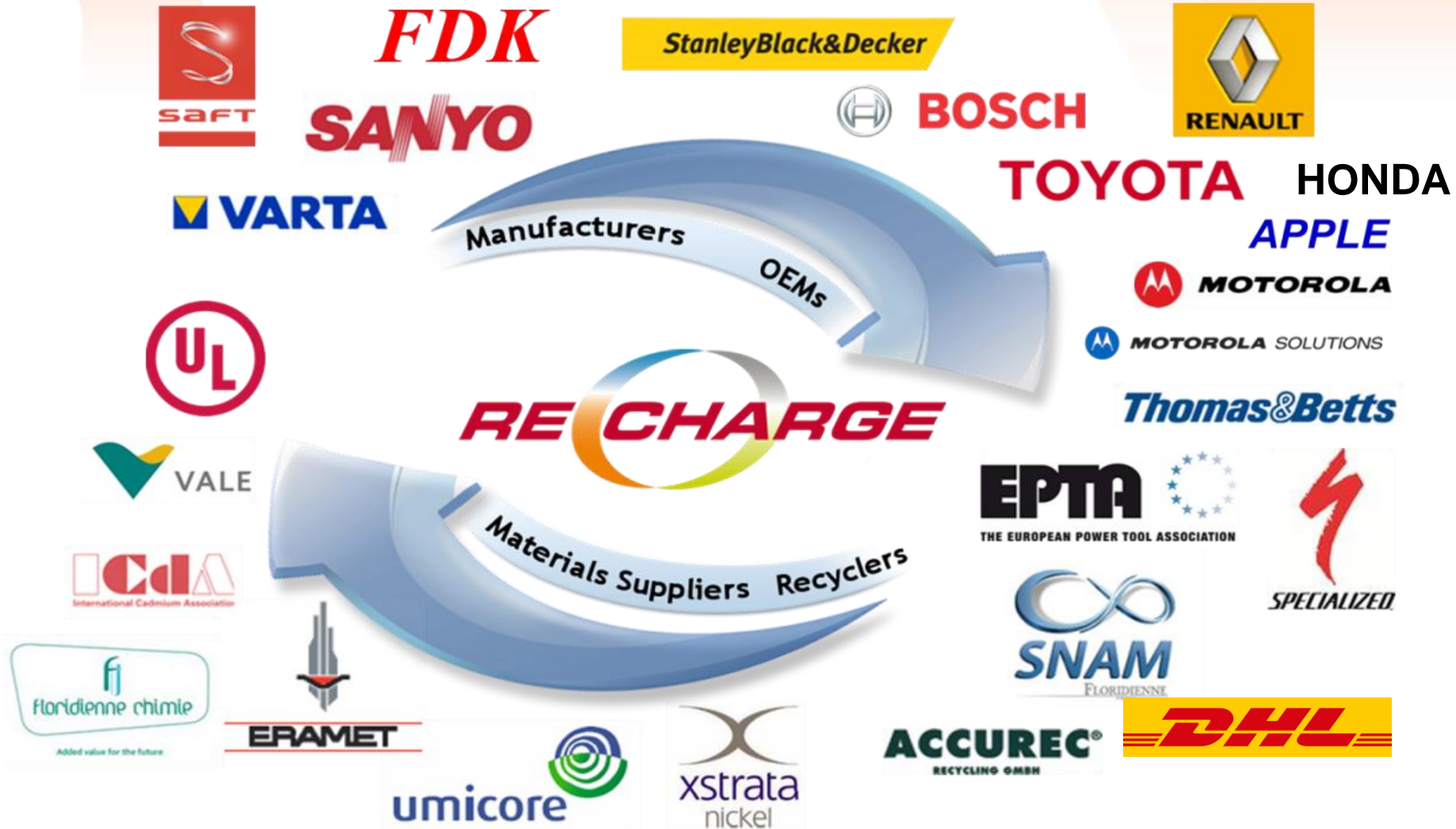
EVE IWG Session #6

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The European Association for Advanced Rechargeable Batteries



Li-ion battery ageing mechanisms

The battery life duration is generally limited by the ageing of the Li-ion battery electrodes and chemistry.

It can be observed through the evolution of two performances criteria:

- ✓ The evolution of the battery capacity
- ✓ The evolution of the battery internal resistance

According usage conditions, other criteria may limit the performances of the battery such as the effect of temperature and the shelf life,....

Li-ion battery ageing mechanisms

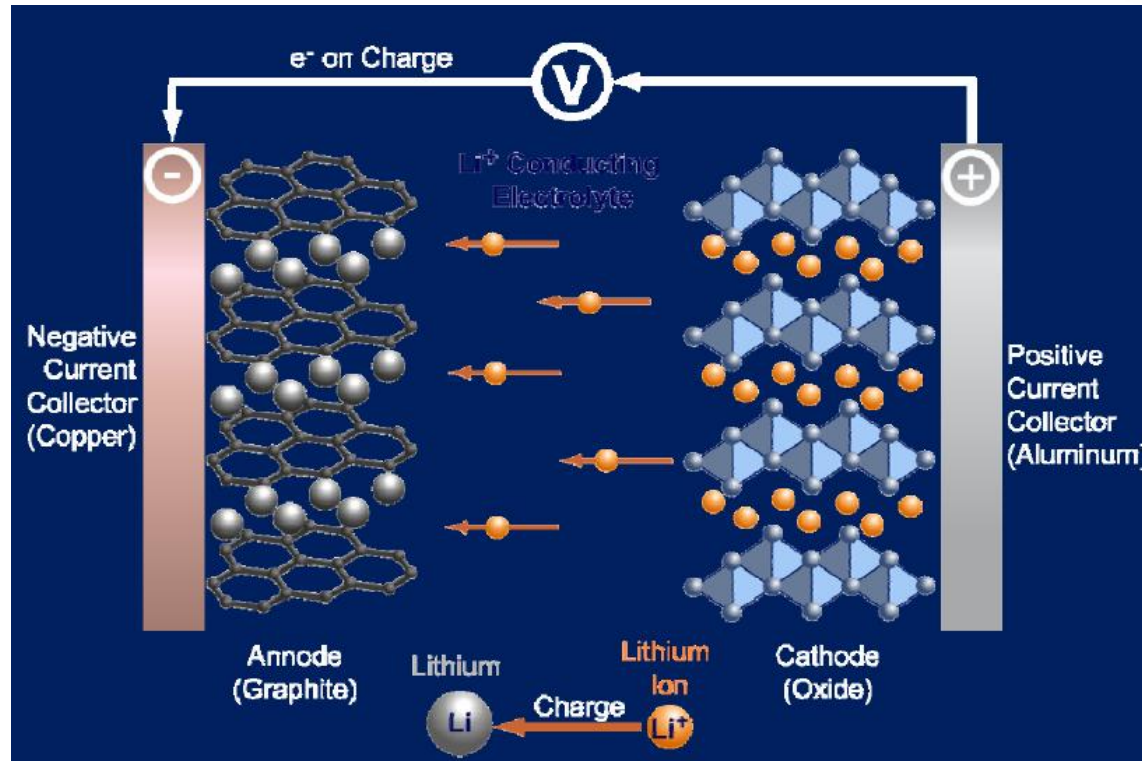
- ✓ The progressive reduction of the battery capacity over life
- ✓ The progressive increase of the internal resistance of the battery as it limits the battery power.

The ageing is often attributed to 2 cumulative mechanisms

- ✓ Calendar life ageing: effect of time and temperature on performances.
- ✓ Cycle life ageing: effect of charge and discharge cycles on performances.

Li-ion chemistries

- The battery chemistry is characterized by the cathode material (LCO, NMC, LFP, etc..)* and the anode material (Graphite, LTO, ..)**



*Cathode materials: LCO= Lithiated Cobalt Oxide, NMC= Lithiated Nickel Manganese Cobalt Oxide,
LFP= Lithium Iron Phosphate.

**Anode material: LTO= Lithium Titanate.

Li-ion batteries key features

- **Multiple Chemistries:**

Li-Ion is a generic term for rechargeable batteries

It covers several types of battery chemistries and several formats for various applications (see next slides).

- **Improving technology:**

This technology is still in an development phase

New chemistries and designs are progressively introduced on the market.

Choices in Li-ion Chemistry

- The type of chemistry will impact performances and safety.

	LCO LiCoO ₂	NCA LiNiCoAlO ₂	NMC LiNiMnCoO ₂	LMO LiMn ₂ O ₄	LFP LiFePO ₄	LTO* Li ₄ Ti ₅ O ₁₂	Si-C*
Cell Voltage, 100%/50% SOC	4.2V/ 3.8V	4.0V/ 3.6V	4.2V/ 3.7V	4.2V/ 3.9V	3.6V/ 3.3V	2.8V/ 2.4V	4.2V/ 3.9V
Energy	++	+++	+++	+	++	-	+++
Power	++	+++	++	+++	++	+	++
Calendar Life	+	+++	+	-	++	-	-
Cycle Life	+	++	++	++	++	+++	--
Safety	+	+	+	++	+++	+++	+
Cost	-	+	++	++	+	-	++

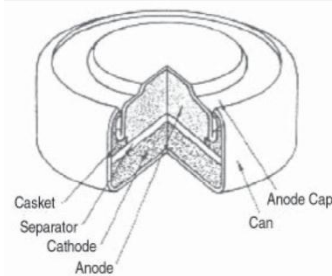
* LTO and Si-C are anodes, which can be combined with any cathode.

The selection of a chemistry for a given application is a trade off between various parameters

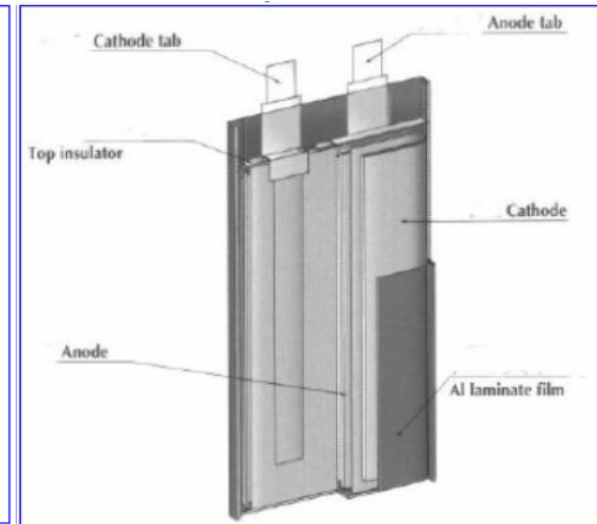
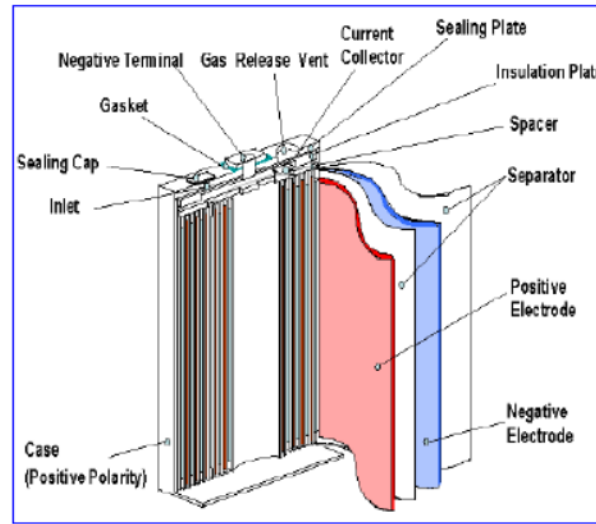
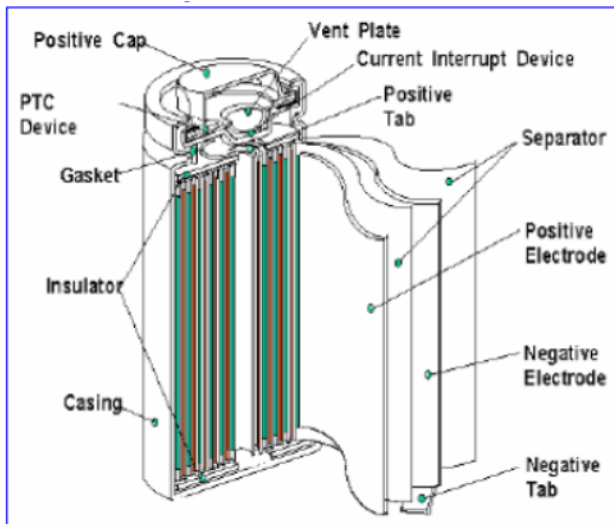
Li-ion batteries / Formats

1. The battery is also characterized by its format.

1. Button cells



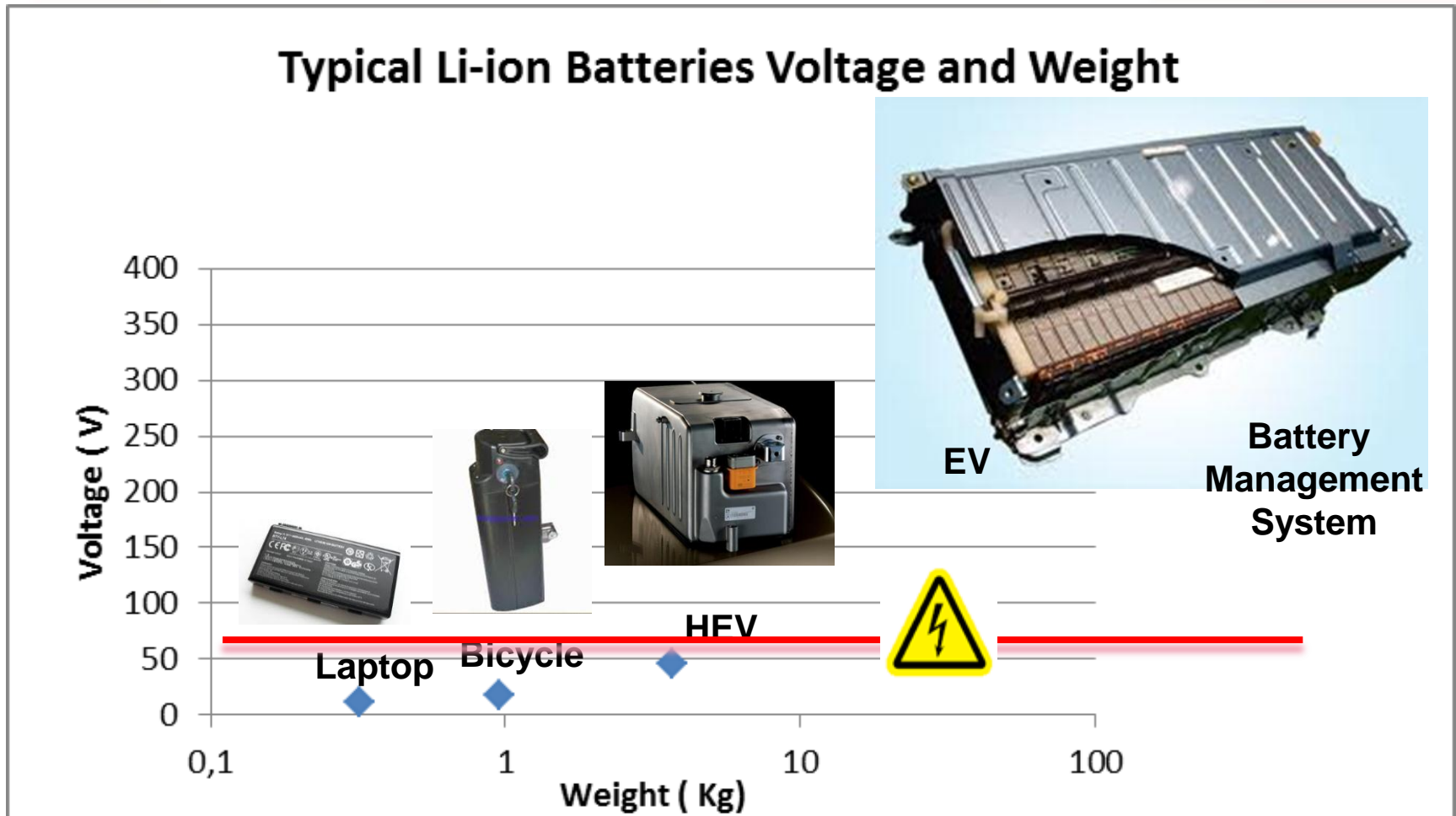
2. Hard cases: cylindrical or prismatic (aluminium welded can) 3. Soft case or « pouch »



Reference: IEEE 1725 Standard

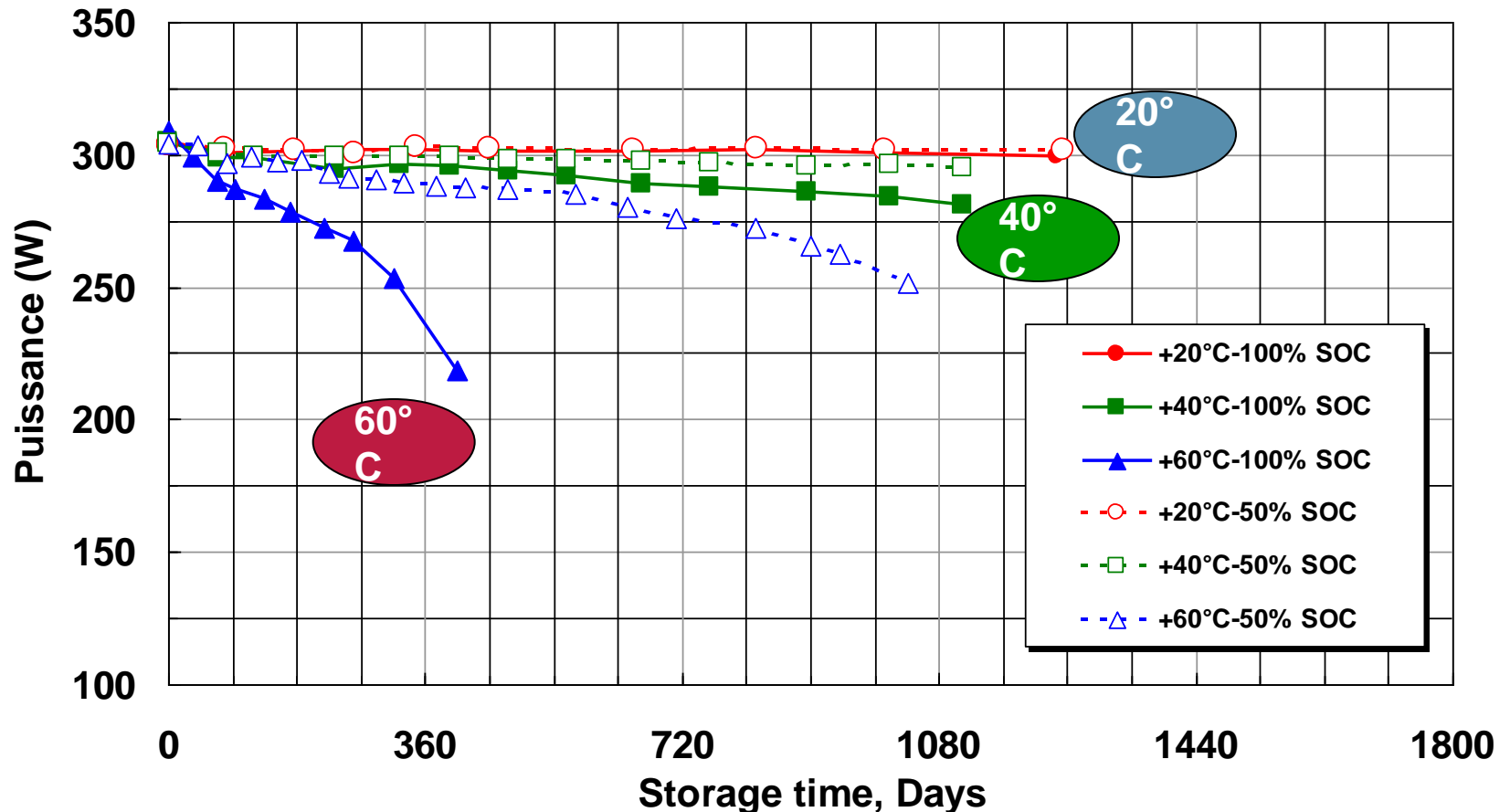
Li-ion packs technologies

The industrial battery is independent of the cell format.



Li-ion ageing: power vs temperature and SOC

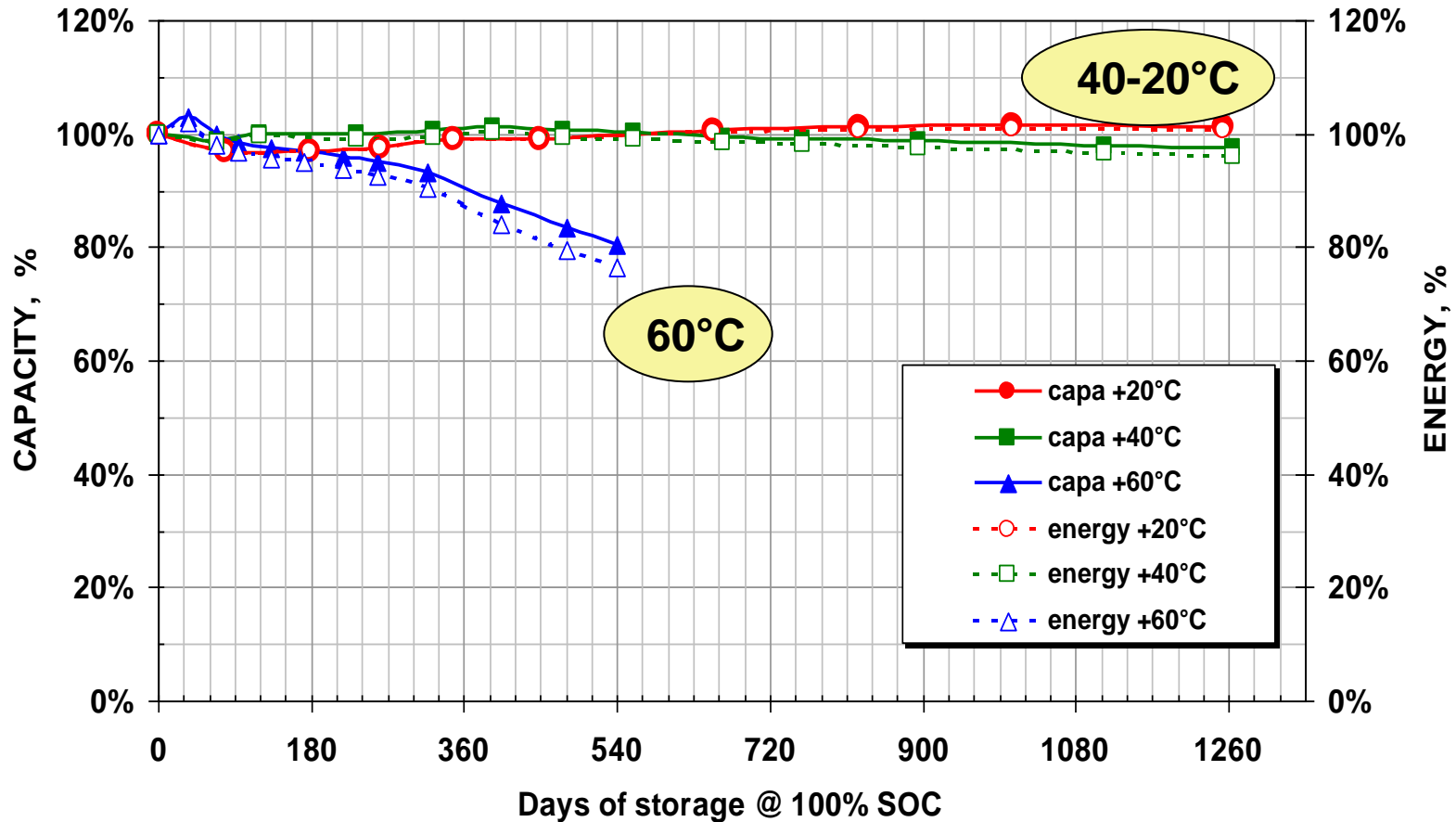
The battery power is impacted by the storage temperature and by the state of charge during storage



Ref: Saft Li-ion NCA/graphite, M. Broussely IMLB12

Li-ion ageing: capacity & energy vs temperature

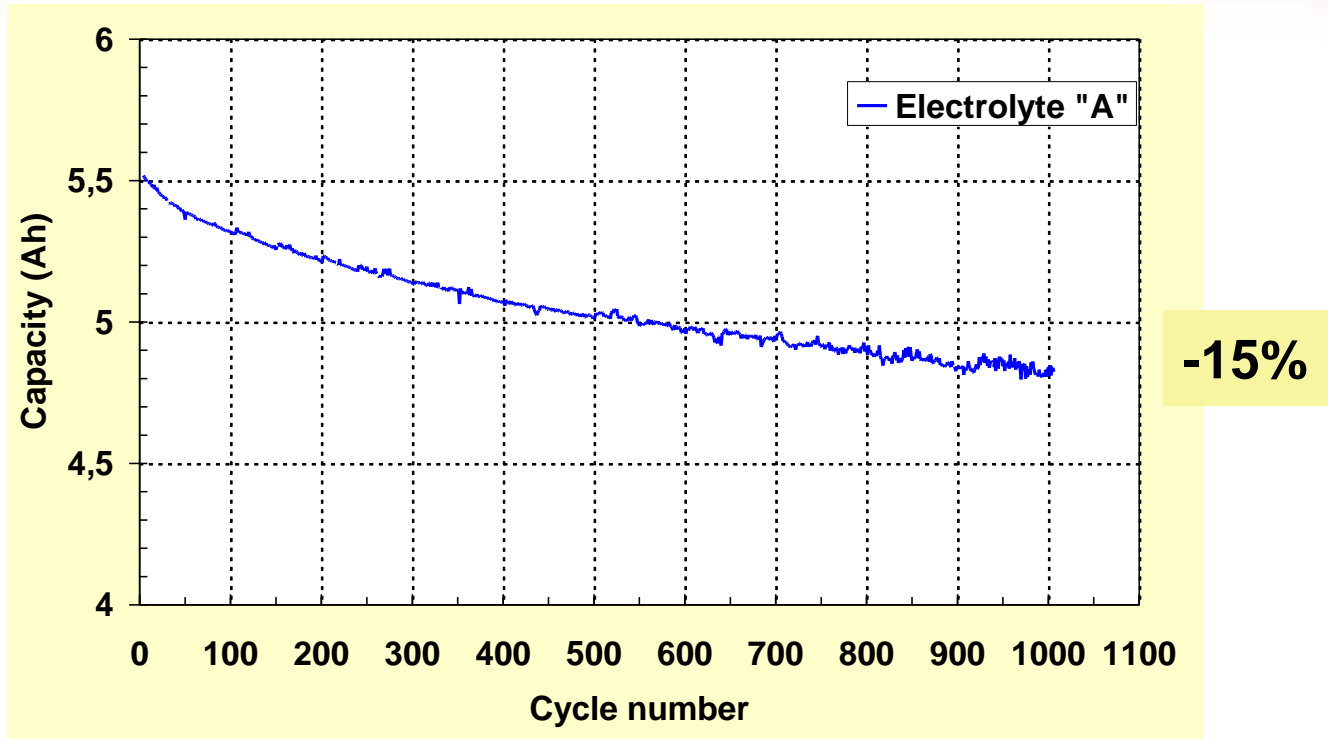
Capacity and energy are impacted by the storage temperature



Ref: Saft Li-ion NCA/graphite, M. Broussely IMLB12

Li-ion ageing: capacity evolution with cycles

The cycle life duration is often measured with cycling at 100% depth of discharge: in this case -15% capacity after 1000 cycles



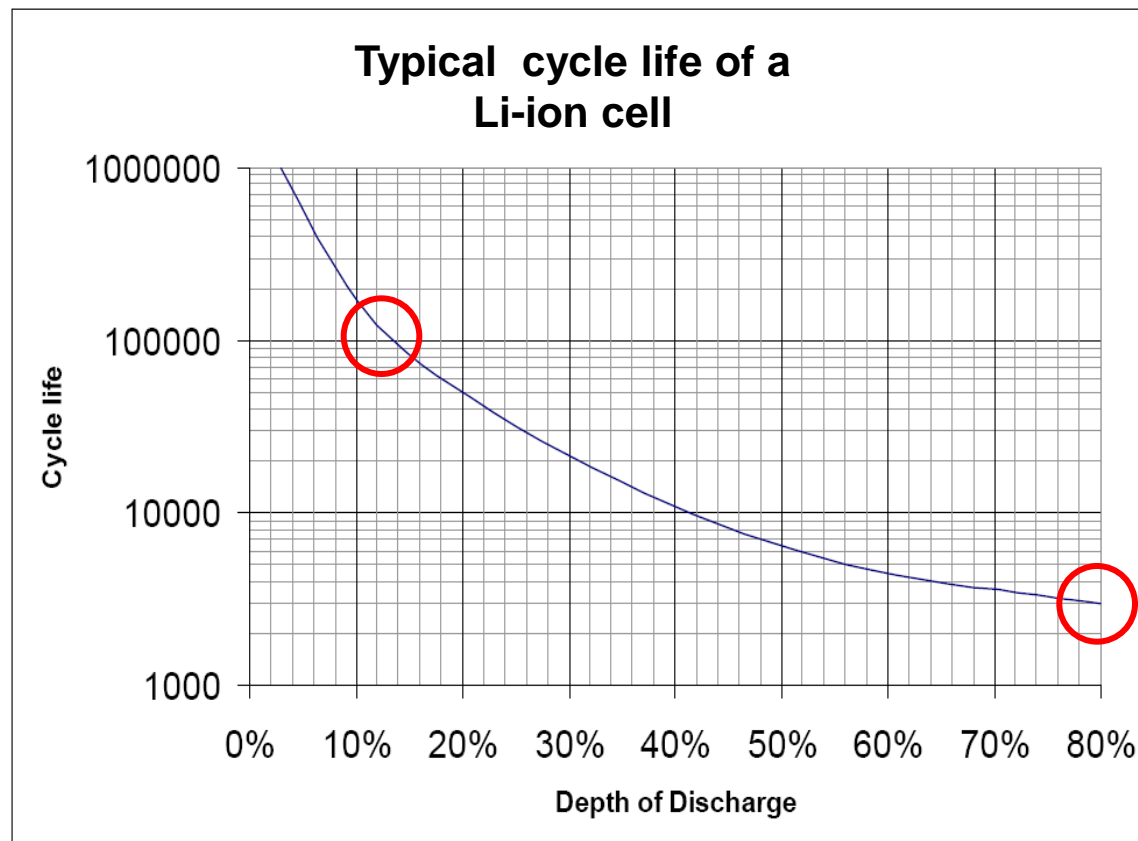
But the large majority of applications do not use 100 % of the battery capacity at each cycle (limited depth of discharge by the user or by the Battery Management System).

Ref: Saft Li-ion LCO/graphite, M. Broussely IMLB12

Li-ion ageing: cycle life vs depth of discharge

The depth of discharge has a large effect on the number of cycle: 1 million cycles can be achieved at low DOD.

=> the battery management system can protect the battery while limiting the DOD



Ref: Saft Li-ion LCO/graphite, M. Broussely IMLB12

Li-ion life duration by application

The battery life duration is determined by 3 key factors

- ✓ The battery design: type and quality of selected materials and components, design of the product.
- ✓ The application constraints: temperature of operation, type of usage (from high power permanent cycling to permanent charge for back-up).
- ✓ The Battery Management System regulation mode: the more efficient is the battery protection, the longer the service life.

Consequently, the service life expectation can be as short as 1 to 2 years, (e.g. in cordless power tool) or up to 20 years (e.g. in in stationnary back-up applications)!