Li-ion Batteries

Lessons Learned from Consumer Electronics

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Presented by:
Bessma Aljarbou

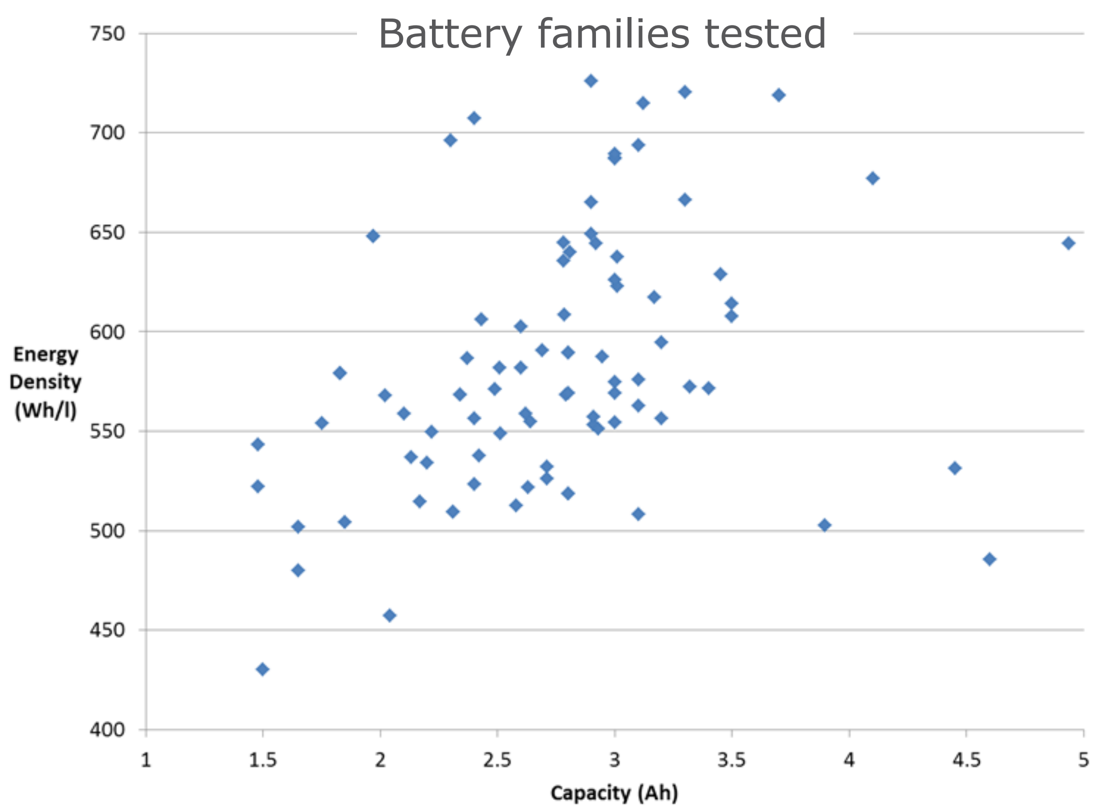
Qnovo's story

- Significant battery damage occurs during charging

- Need for greater intelligence when operating and managing the battery

- Our Core Technology
  - Adaptive Control Algorithms
  - Predictive Analytics

Qnovo - Six years of Li-ion battery experience



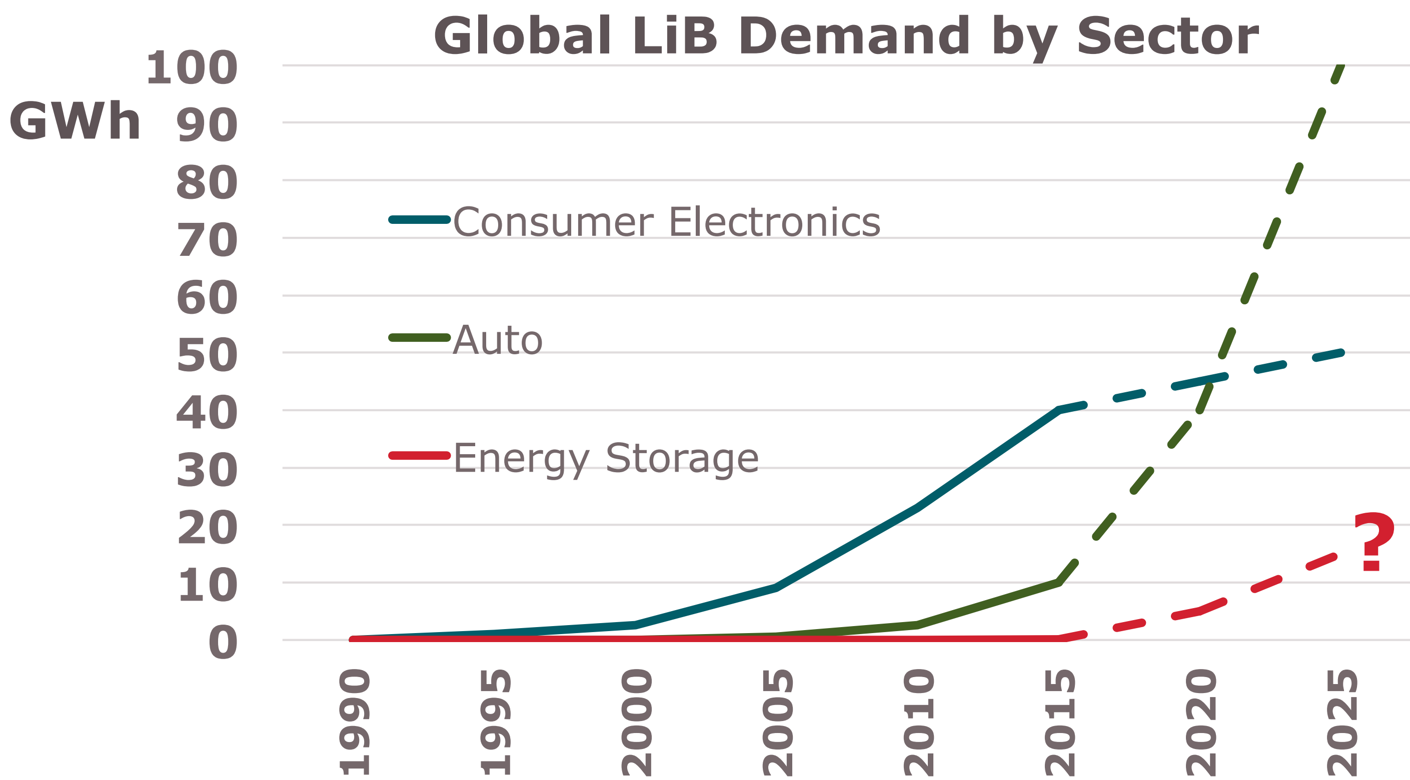
10 lithium-ion suppliers

>100 cell families

> 1 million lab cycles

> 10 million devices shipped

Energy Storage is subject to Consumer Electronics & Automotive trends



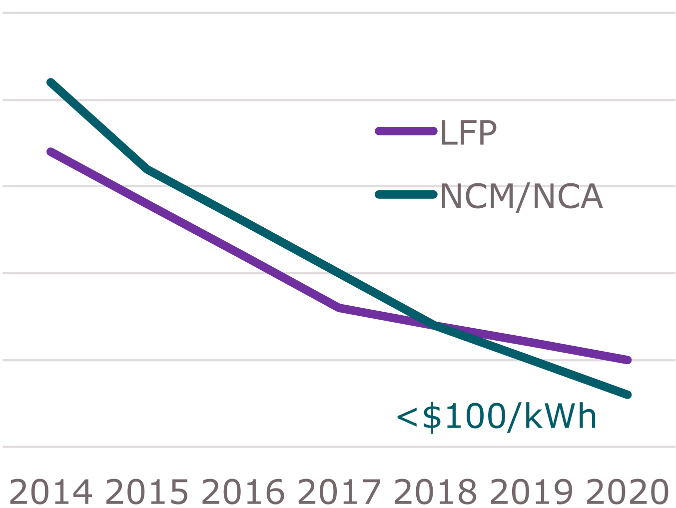
Sources: itdcw.com, Gao Hua Securities Research, 2017 iNEMI Roadmap, Roland Berger (2012), Pike Research (2013), AAB (2013), Avicenne Energy (2014)

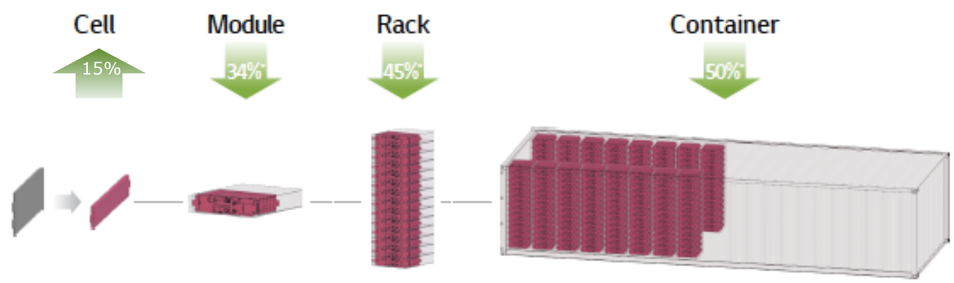
Battery performance by application

Specs	Consumer Electronics	Automotive	Energy Storage
Cycle Life	500+	1,000+	3,000+
Charge Rate	Fast	Fast	Slow to Fast
Battery Size/Weight	Matters	Matters	Less Relevant
Chemistry Selection	**LCO**	**NCM / NCA**	**LFP**
Energy Density	High	High	Low

NCM/NCA becoming dominant chemistry for energy storage

Falling NCM/NCA Battery Cost + Lower Balance of System Cost due to higher energy density = Lower Total System Cost…





But you sacrifice cycle life and have greater safety concerns

Graph Sources: BAIC, Gao Hua Securities Research.
Source: LG Chem

Handicapping energy storage system design to reach targets

Specs	Energy Storage
Chemistry	NCM / NCA
Energy Density	Low
Charge Rate	Slow
Capacity Usage	<100%
Cycle Life	1,000+?
Safety	Safe?

In order to:

- Reach cycle life goals
- Reduce safety concerns

Handicap the system:

- Continue to use low energy density cells
- Avoid fast charging
- Oversize system and limit capacity usage

Welcome to the Consumer Electronics World!

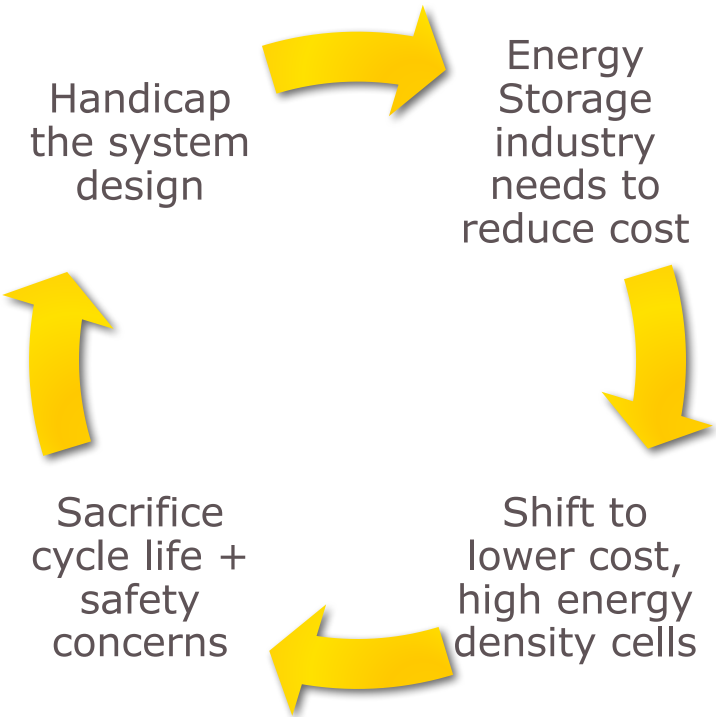
Plenty of safety codes and standards for consumer electronics

Organization	Standard
IEC	IEC 62133. Safety standard for nickel and lithium ion cells and batteries intended for portable applications. IEC 60086-4:2014. Requirements and tests for primary lithium batteries to ensure their safe operation. IEC 61960:2011. Specifies requirements for secondary lithium single cells and batteries for portable applications. IEC 62281: Safety of lithium cells during transport.
ANSI	ANSI C18.3M, Part 2: Safety standard for portable lithium primary cells and batteries
UL	Standards for lithium batteries, covers requirements and testing of cells (UL1642) and batteries (UL2054).
IEEE	IEEE 1625. Requirements for rechargeable batteries for laptop and tablet computers. IEEE 1725. Requirements for rechargeable batteries for cellular telephones.
JIS / JEITA	JIS C 8714:2007. Safety tests for portable Lithium Ion secondary cells and batteries for use in portable electronic applications. JEITA. A guide to the safe use of secondary lithium ion batteries in notebook-type personal computers, April 20, 2007.
UN / DOT	UN/DOT 38.3: Transportation safety for lithium-based cells and batteries.

Example of active safety management

- **Closed-loop** adaptive charging is inherently safer than **open-loop** CCCV or step charging
- Real-time charging optimization
  - To each individual battery
  - For every charge cycle
- Continuous real-time safety checks
- Predictive safety: safe shutdown of problem cells

Summary



Best way to break the cycle is to get smart about the battery

- Adaptive and Closed Loop
- Ongoing safety checks
- Predictive analytics

Qnovo Inc.
39655 Eureka Drive
Newark, CA 94560
www.qnovo.com