Batteries 101

Lunch & Learn

We will begin in a few moments. We encourage you to use a separate phone to dial-in for the audio and use your computer for the presentation material only.

Participants are automatically muted but may ask questions via your control panel.

If there are problems with the audio, please try dialing an alternate (US dial-in is 213-929-4221).

We will be taking questions at the end but feel free to submit questions at any time.

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Batteries 101

Thinking of a battery powered design? Learn the basics of what is available, the limitations, and the advantages.

- Rechargeable vs. Primary (Non-Rechargeable)
- Power vs. Energy
- When Voltage Matters (& Current too)
- And More…Charging, a bit of Chemistry, etc.

Presenter: Dan Friel, National Business Development Manager, VARTA

Linked-In: Dan Friel: https://www.linkedin.com/in/dan-friel-2004

Email: dan.friel@varta-microbattery.com

Batteries 101
Definitions

Just the Basics…

- Cell vs. Battery
  - Cell is a single element
  - Battery is a collection of cells, often with a connector, etc.
- Battery Energy = Battery Capacity = How long Battery will run
  - Amp-Hours or Watt-Hours (has a time component)
- Power vs. Energy
  - Power is rate (of current): Usually expressed in Watts = Volts x Amps
  - Energy is duration of Power: Has a time component, i.e. Amp-Hours, Watt-Hours
    - Watt-Hours = Volts x Amps x Time

Batteries 101

Rechargeable vs. Primary (Non-Rechargeable) Cells

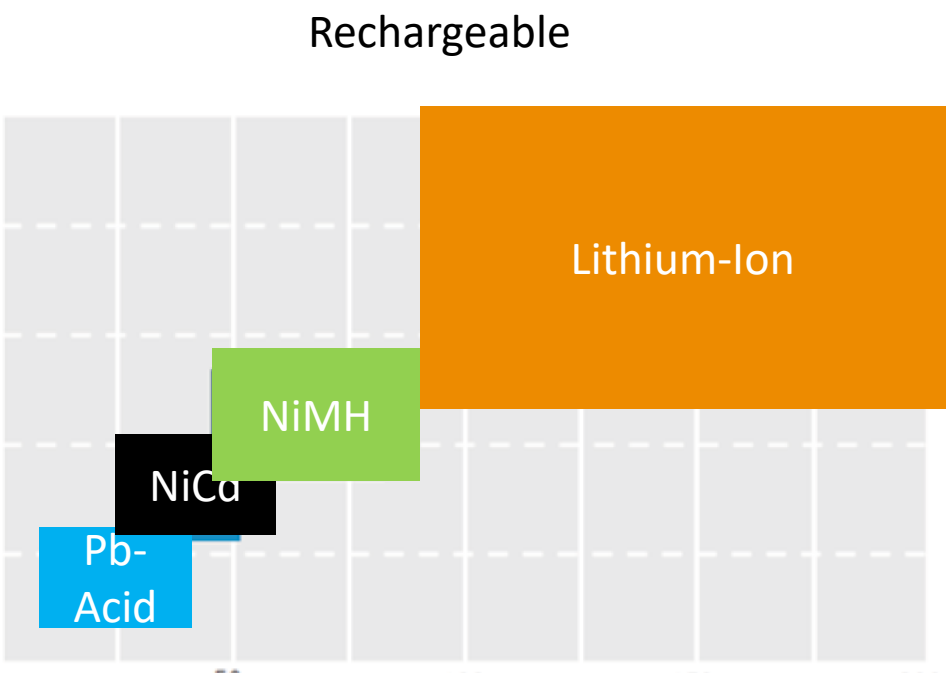
- Re-chargeable = Re-usable
  - Higher Power than Primary
  - Self-discharge limits shelf-life
- Primary = One time usage
  - Higher Capacity than Rechargeable
  - More stable (flat) voltage & very long shelf-life

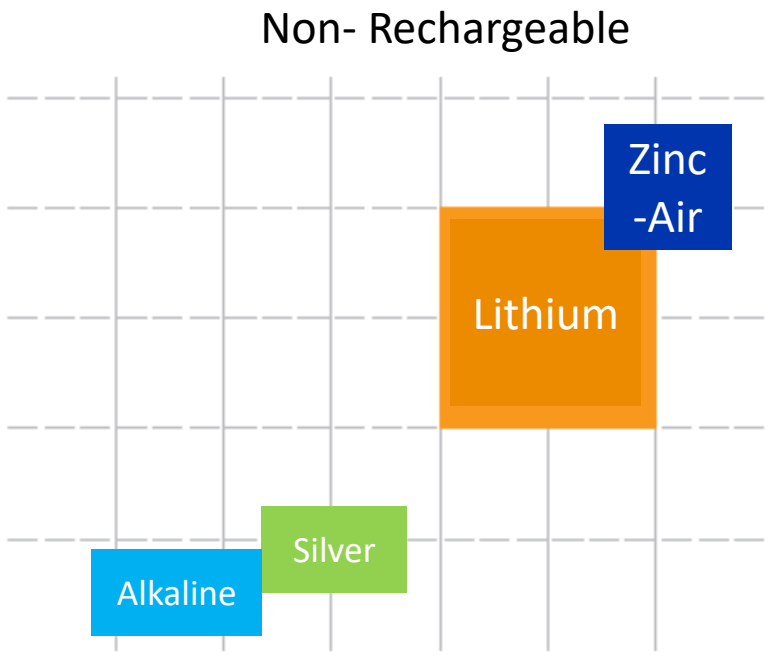
- Both come in many chemistries, sizes & shapes:
  - But size does not determine Rechargeable or Primary
  - Size does not determine Capacity or Voltage

Batteries 101

Rechargeable vs. Primary: Energy Density differs greatly (as does Power capability)

- Gravimetric: Density based on weight
- Volumetric: Density based on size





Batteries 101
Primary or Rechargeable

What Type of Battery?

- Power Consumption of the Device and desired operating time determines the amount of Energy or Capacity that is needed.
- Needs change as Power Consumption increases.
- Here are some examples:
  - TV remote control with a primary Alkaline or Lithium Cell lasts a year or more
  - Hearing-aid primary Cell runs for a week
  - Bluetooth ear-bud prefers a small rechargeable Cell to run for hours
  - Cell Phones, Laptops require larger rechargeable Batteries (<100 Wh)
  - Mobile Robotics (fork-lifts, etc.) require larger rechargeable Battery Systems (>100 Wh)

Batteries 101

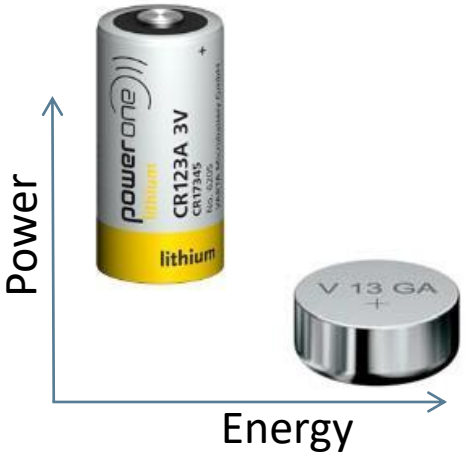
Power vs. Energy

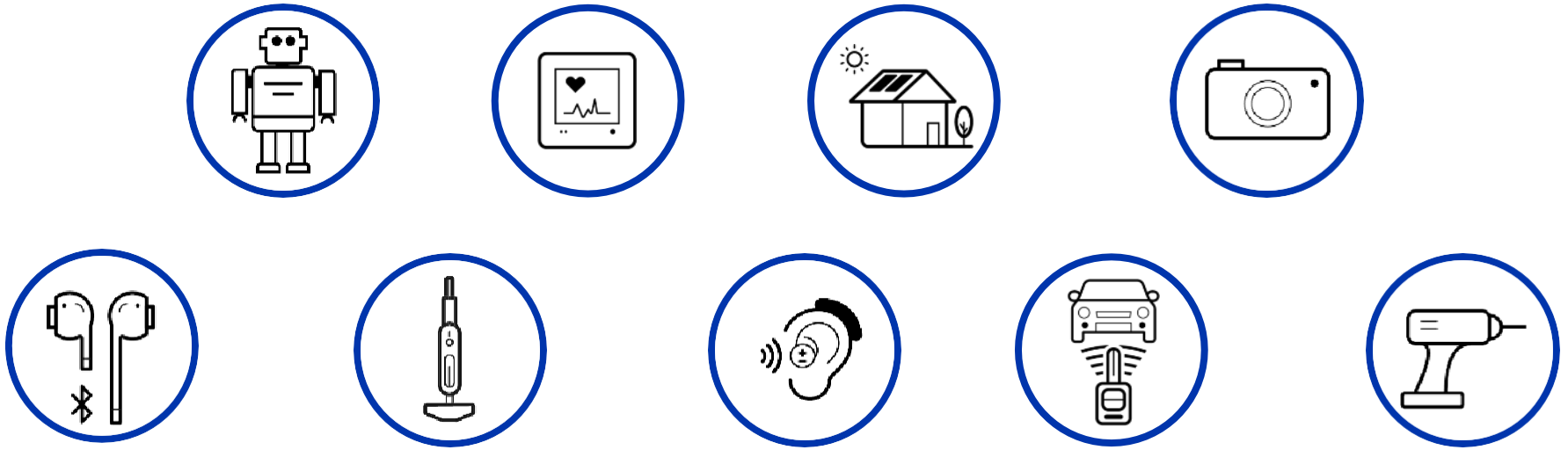
- Power = High Current, Short Duration
- Energy = Low/Medium Current, Long Duration

Batteries 101

Power vs. Energy – Why this is Important

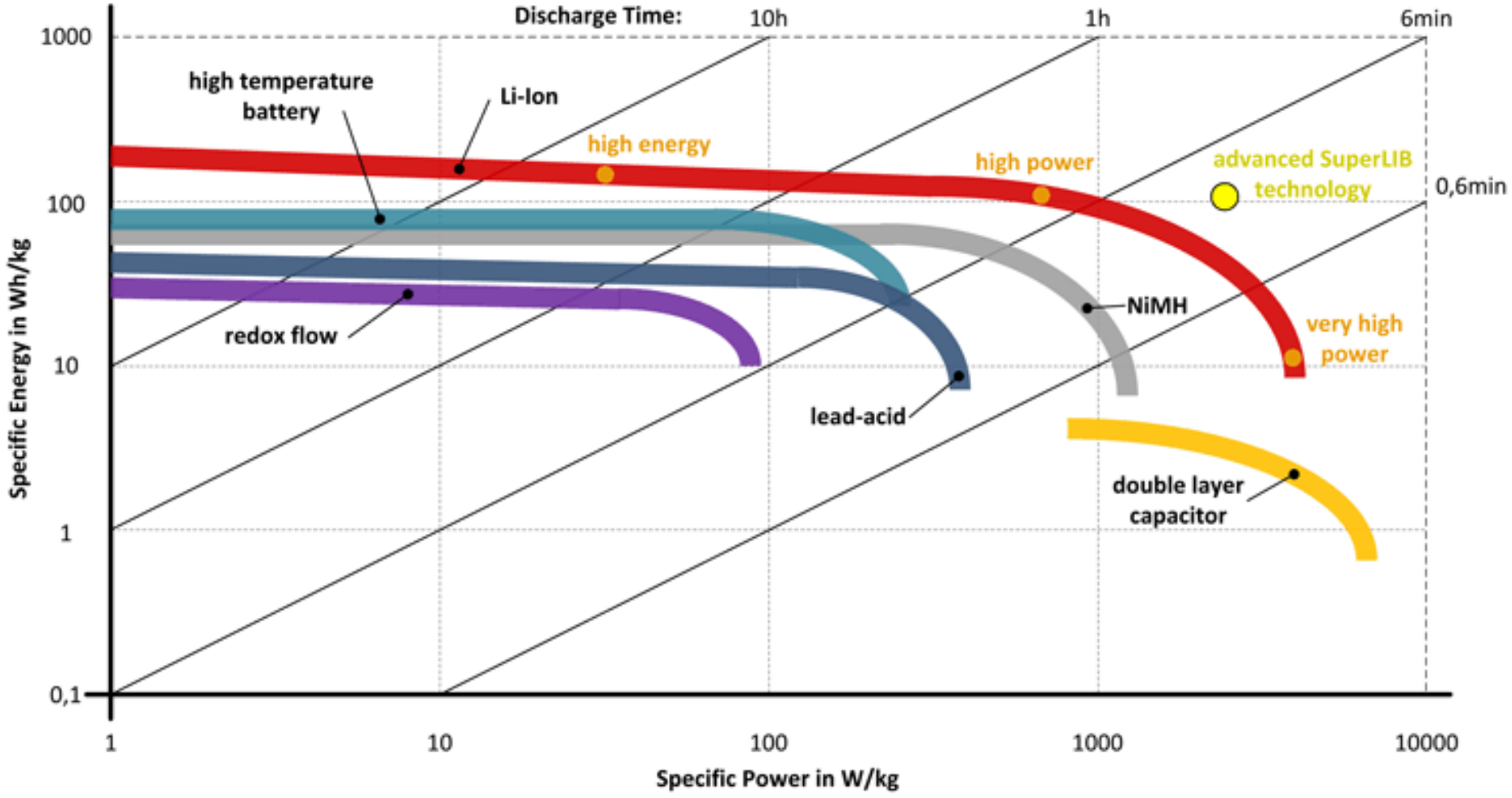
- High Power Cells have lower Energy
- But High Energy Cells have lower Power





Batteries 101
Power vs. Energy – Rechargeables

Cell Chemistry Comparisons: Energy (Run-time) vs. Power (Peak)

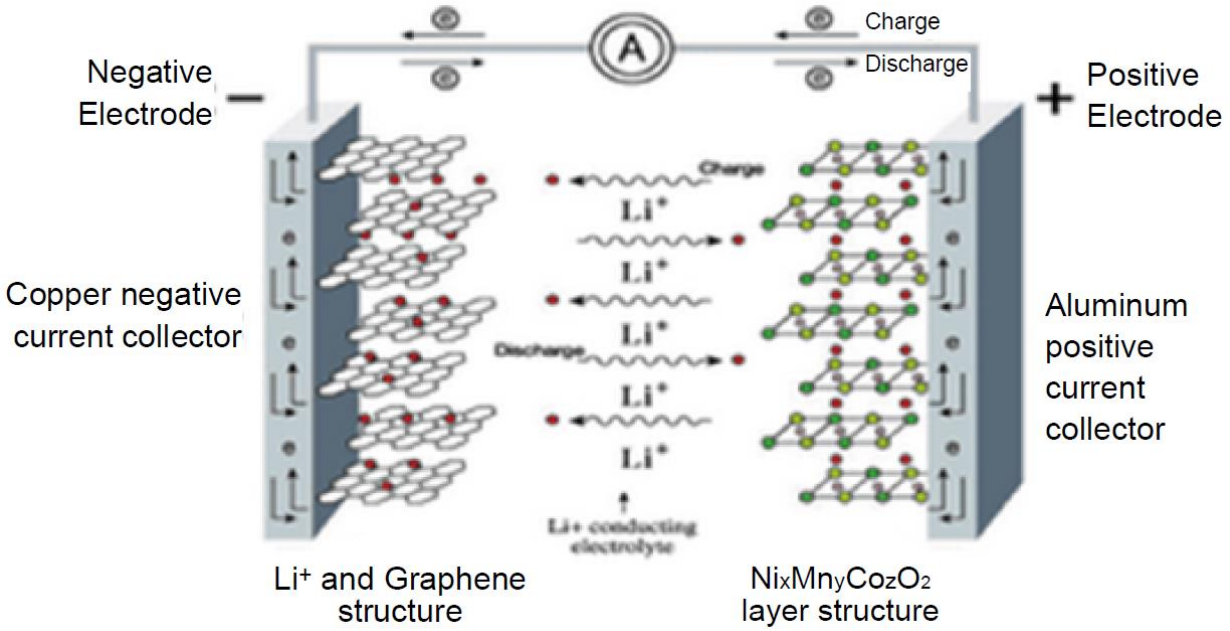


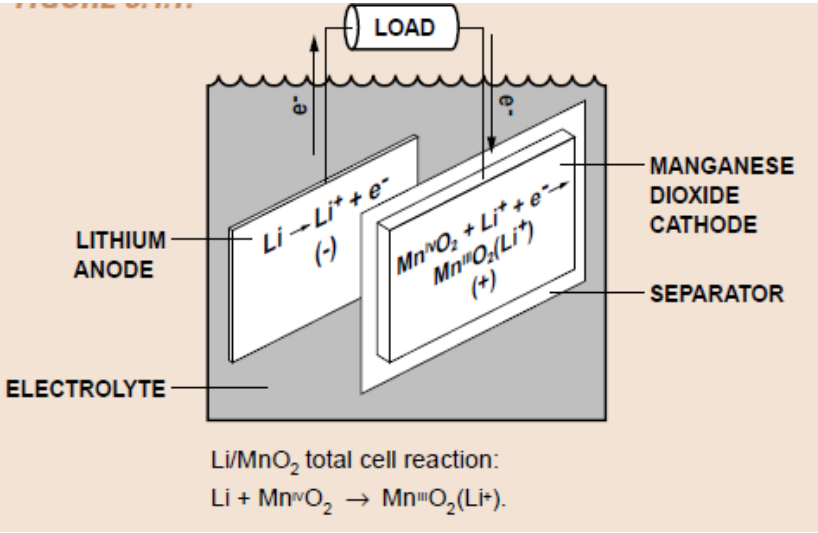
Sources: Avicenne

Batteries 101

What's Inside: Chemistry 101

- Anode, Cathode, Electrolyte, Separator
- Same for Rechargeable or Primary



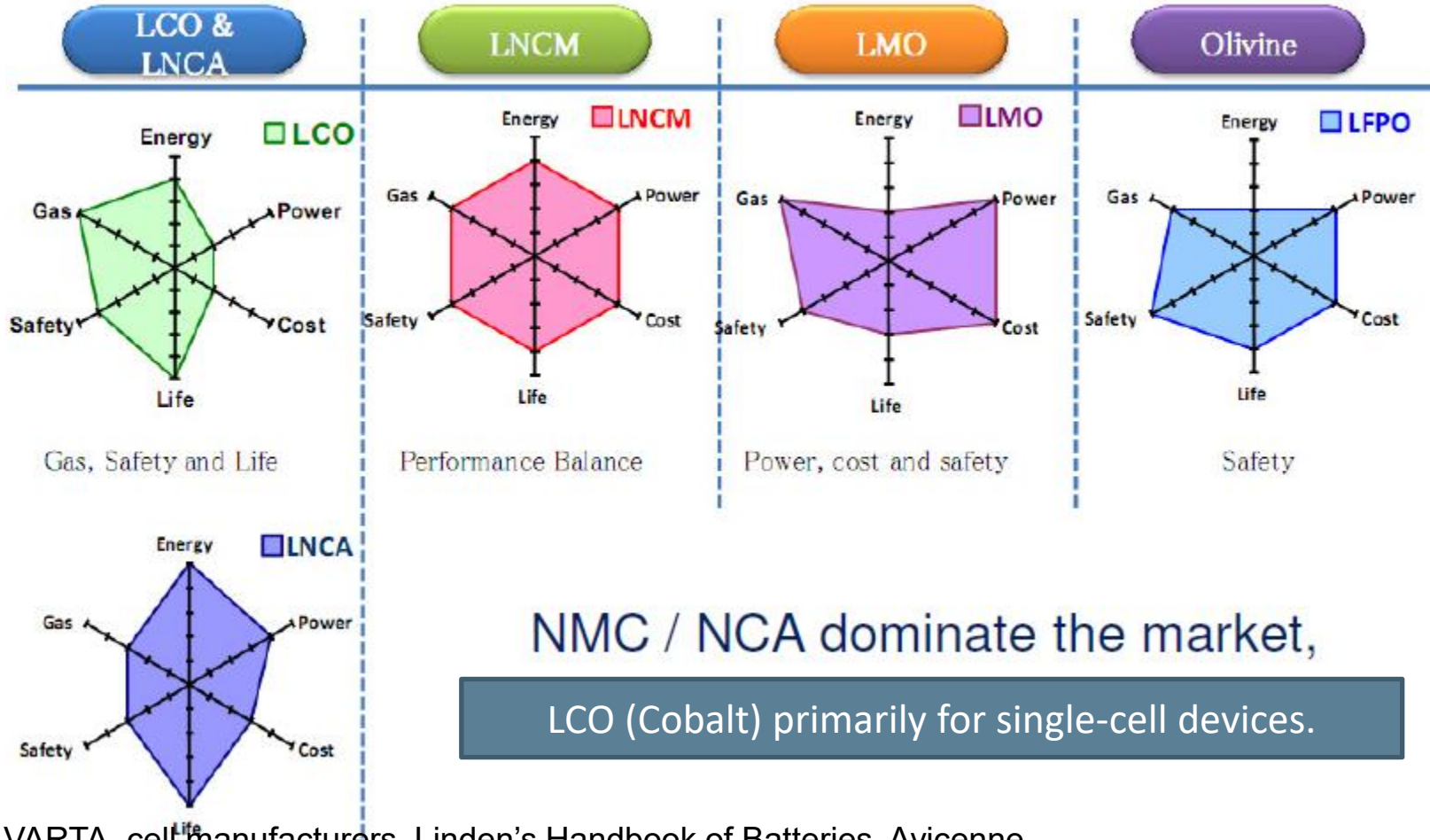


Sources: VARTA and Duracell

Batteries 1010
Lithium Ion Cell Chemistry Options

Cell Chemistry Comparisons – Top Level

Comparison of cathode materials



NMC / NCA dominate the market,

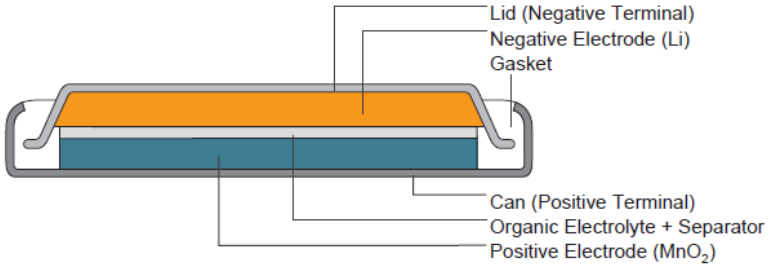
LCO (Cobalt) primarily for single-cell devices.

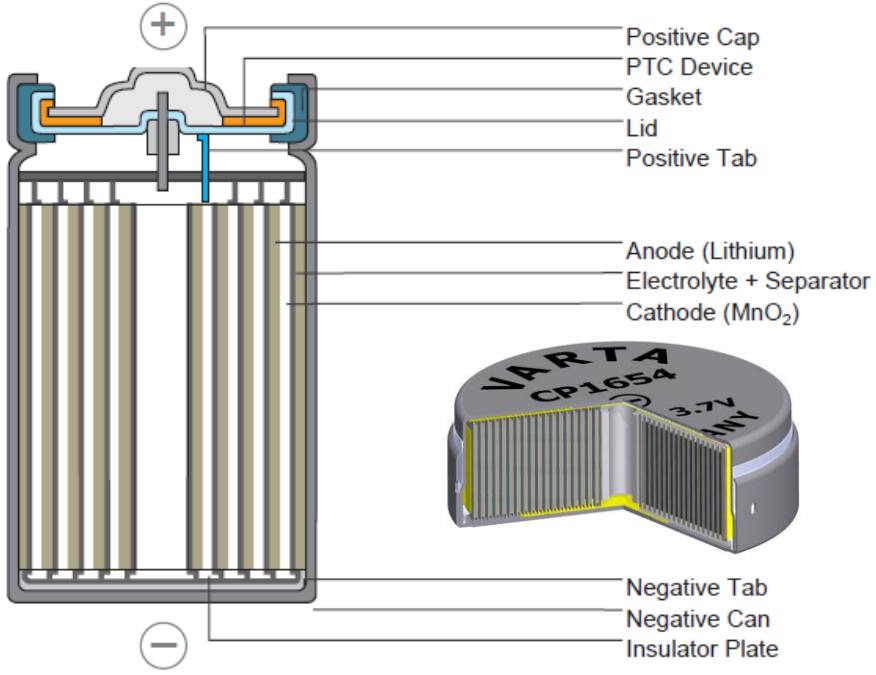
Sources: VARTA, cell manufacturers, Linden's Handbook of Batteries, Avicenne

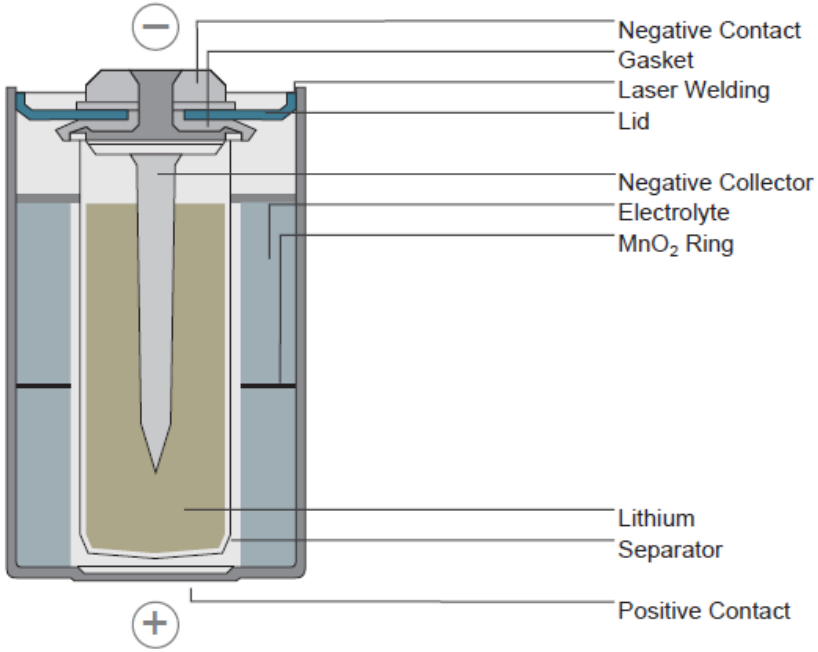
Batteries 101

Construction:

- 101 ways to build a Cell
- Construction determines many criteria:
  - Capacity, Power, Safety … & Cost







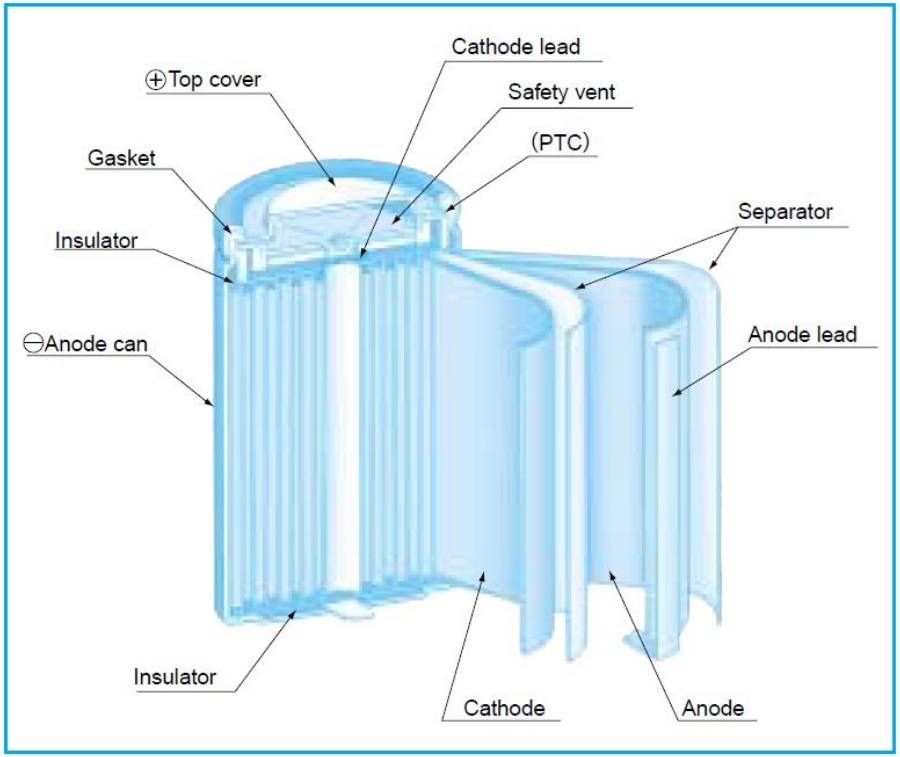
Batteries 101

Cell Types: Rechargeable Li-Ion

- Cylindrical:
  - 18650, 21700, 26650 & others
  - Best Rate Capability: Fast Charge & Discharge
  - Lowest Cost & Highest Energy Density
  - Other sizes exist: 18500, 14500, etc.

Cell Types: Rechargeable NiMH/NiCd

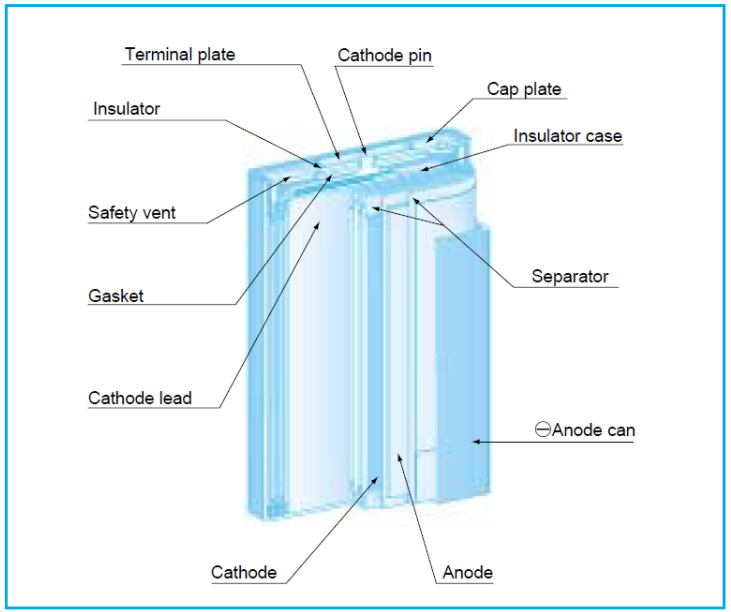
- Cylindrical:
  - Match Alkaline cell sizes: AA, C, D, etc.
  - Alternate sizes 4/3A, 4/5A, 2/3A, Sub-C

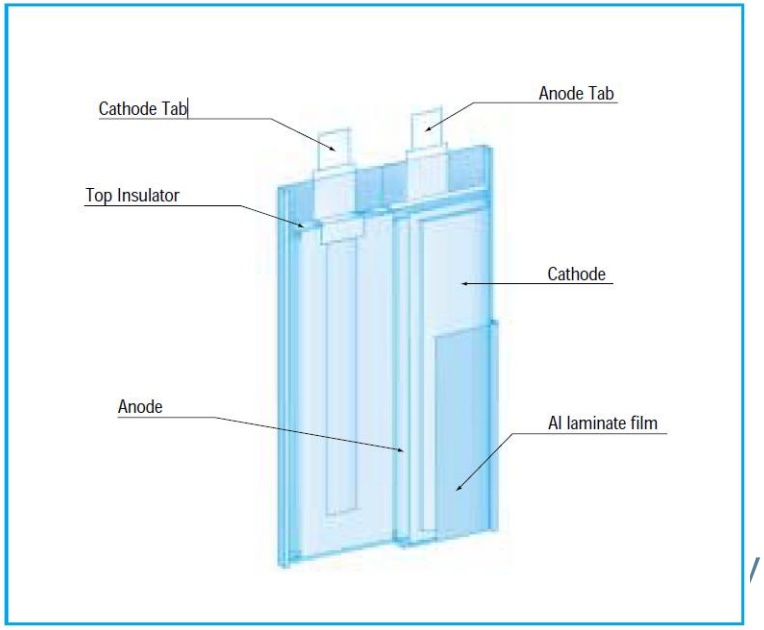


Images courtesy of Sony (now Murata)

Cell Types: Rechargeable Li-Ion

- Prismatic: 103450 = 10 x 34 x 50 mm
  - Good Energy Density; Good Charge & Discharge
  - Limited Sizes (z x 34 x 50mm most common & available)
- Pouch/Polymer: Various sizes – Usually thinner than 10mm
  - Lower Energy Density (due to thin size); Reasonable Charge & Discharge
  - Thinnest options available; but more X-Y-Z size options – has swelling issues





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Images courtesy of Sony (now Murata)

Batteries 101

Cell Types: Rechargeable Li-Ion

- Cylindrical: 18650, 21700 (also 26650)
  - Lowest Cost & Highest Energy Density
  - Best Rate Capability: Fast Charge & Discharge

Industry transitioning to 21700 cell size

- Prismatic: 103450 = 10 x 34 x 50 mm
  - Good Energy Density
  - Limited Sizes (z x 34 x 50mm most common)
  - Good Charge & Discharge Capability

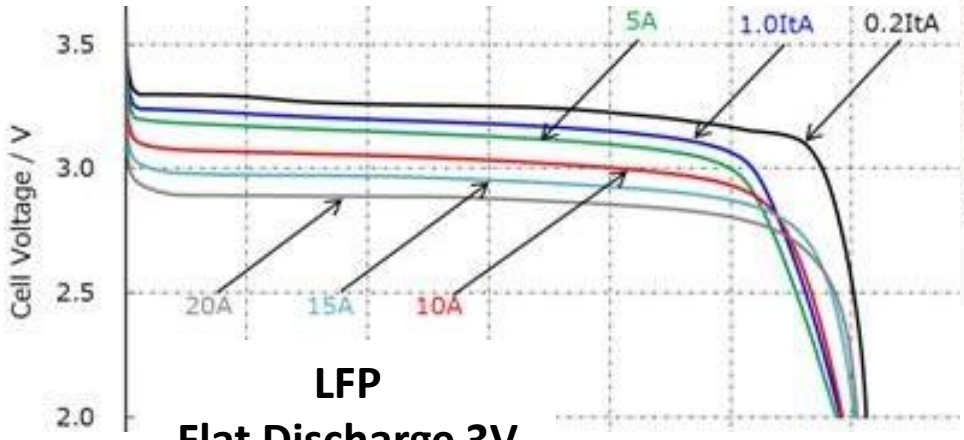
Manufacturers moving to larger sizes to support Electric Vehicle markets

- Pouch/Polymer: Various sizes – Usually thinner than 10mm
  - Lower Energy Density (due to thin size)
  - Thinnest options available; but must consider swelling
  - Okay Charge & Discharge Capability

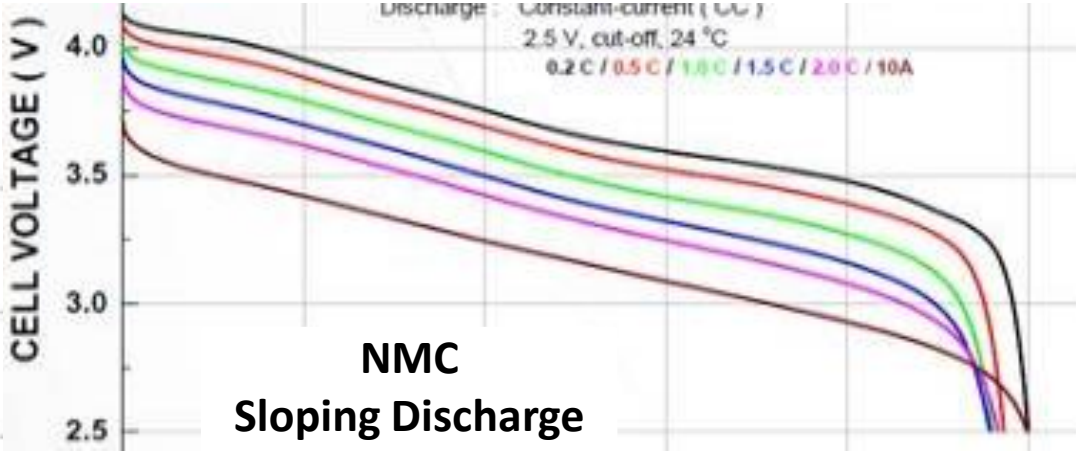
Cell sizes disappearing – once abundant variety is dwindling (variety of phones & tablets decreasing)

When Voltage Matters – and Current too

- Battery is NOT a constant voltage output device
  - Significantly altered by magnitude of discharge (load) Current
  - Each chemistry is different



LFP
Flat Discharge 3V

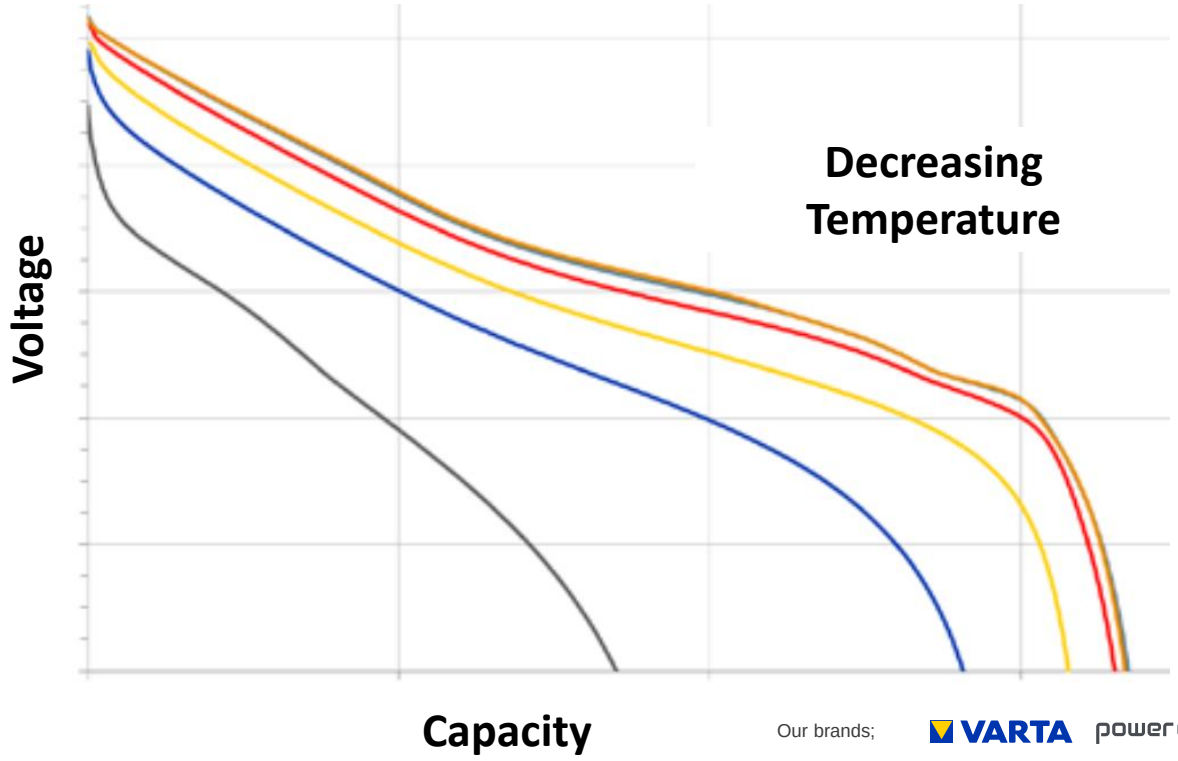


NMC
Sloping Discharge
4V ~ 3V

Batteries 101

When Voltage Matters – and Temperature too!

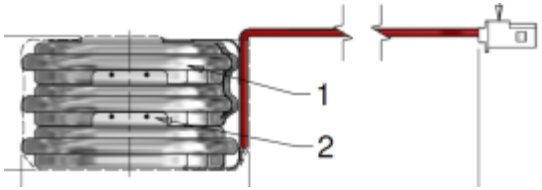
- Battery is NOT a constant voltage output device
  - Significantly altered by Temperature

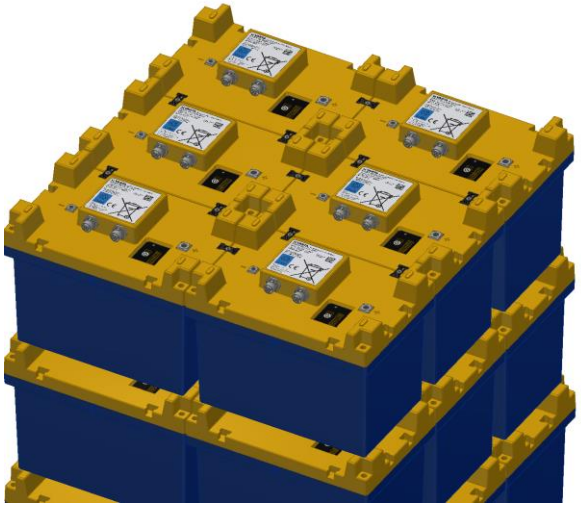


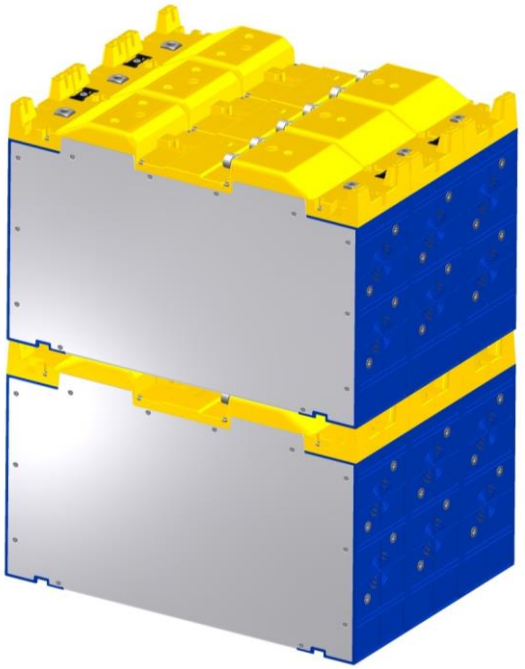
Batteries 101

When Voltage Matters – for Your Device

- Higher Voltage does More Work
  - Current decreases as Voltage increases: Power = Voltage x Current
  - Effects of heating are **Current²** x Resistance
  - Stacking in Series to increase Voltage
  - Stack in Parallel to increase Capacity

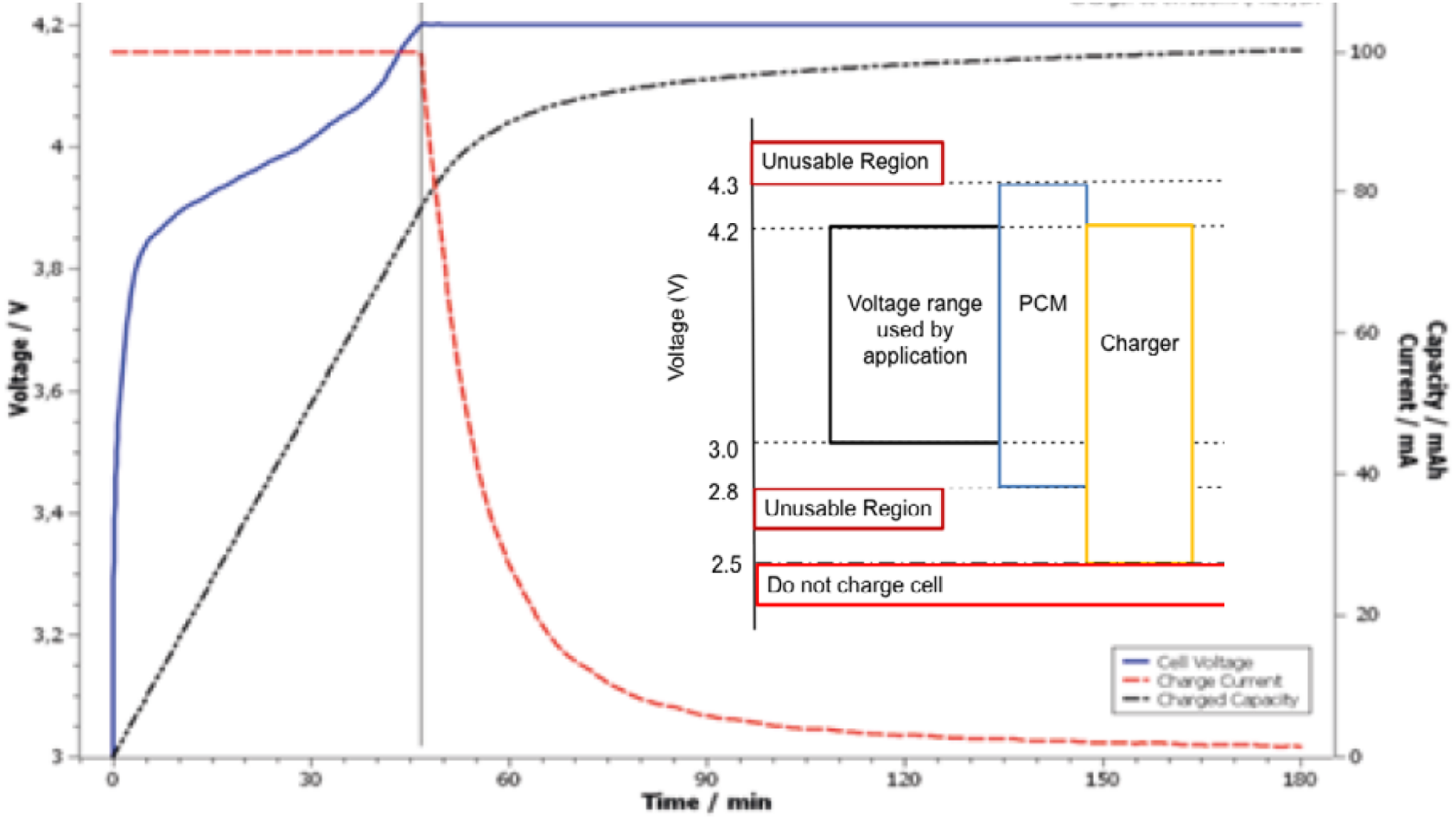






Batteries 101
What About Charging?

Charging: Another Webinar



Batteries 101

Putting it All Together: Decision Topics

- Rechargeable or Primary
- Power or Energy requirement
- Operating Voltage

Lots more to decide…

- Is this a one-time design or will the Battery be the first in a line of products?
- How critical is the Battery to the operation of the device?
- What is the operating Environment – typical or extreme?
- Expected Product Life-Cycle: Few years to 10+ years?
- Regulatory Certifications: UN, UL, IEC, others

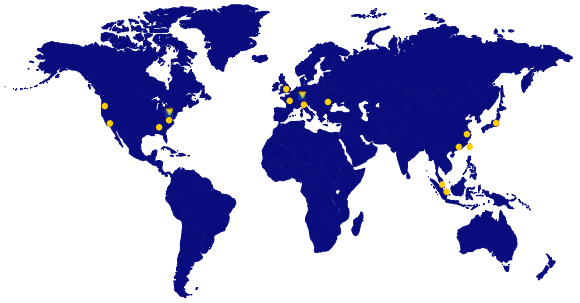
Batteries 101
Decisions – Decisions…

Custom Design	Product Requirements	Application Specific Standard
Product Family	**Product Line**	One Time Design
Extreme	**Environment**	Typical
5+ Years	**Product Life Cycle**	Few Years
FDA, IS, other	**Regulatory Certifications**	UN, UL, IEC
Power or Energy	**Power or Energy Device**	Energy
Expandable	**Capacity**	Fixed
Unique Shape and/or Non-Embedded	**Size & Shape**	Rectangle or Square, Embedded Battery
Proprietary	**Interface**	Industry Standard Protocols
Fast, Regen	**Charging**	Slow, After Usage
On-board or Wireless	**Charging Methods**	Traditional
NRE	**Design Costs**	Low
Unit $ x EAU > $3M	**Production Volumes**	Unit $ x EAU < $1M
2 to 6 months	**Timing**	Immediate

Batteries 101

Finding the Right Battery Partner:

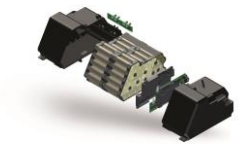
- Technology Leader
- Well known in the Industry
- Standard line of products in a variety of sizes
- Previous Custom designs with well known customers
- History and Industry Experience in Battery systems
- High-volume Manufacturing Expertise (not just a Design House)
- Worldwide Reach & Support
- Multiple Manufacturing & Design locations
- Reputable firm – ideally a public company
- Financially Stable & Reliable



VARTA Worldwide

VARTA AG

MICROBATTERIES & SOLUTIONS

Healthcare	Entertainment	Solutions
		

Largest Manufacturer of Hearing Aid Cells (1B/yr)

www.VARTA-Microbattery.com

HOUSEHOLD BATTERIES

Consumer Batteries	Energy Storage
	

Standard & Custom Battery Packs and Energy Storage

www.VARTA-Storage.com

Consumer Coin & Cylindrical Cells; Home Energy Storage

www.VARTA-Consumer.com

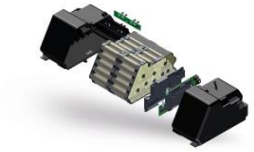
More than 130 years of innovation

1990
VARTA Lithium Cells

1995
VARTA Primary Lithium Cell assembly
+
Wire connector

2000
VARTA Customized Lithium-Polymer Pouch
+
Safety Electronic

2010
VARTA PowerPack Solutions
+
Mechanical and Electrical Design



2011
VW VARTA Joint Venture
+
New material technologies

2012
VARTA Storage Residential Energy Solutions
+
Cell and charge balancing, Power interface

2014
VARTA CoinPower Series
+
Innovative Cell-Design for highest Performance & Safety

2016
VARTA Storage Commercial Storage Solution
+
Adressing multiple energy management functionalites

2018
New VARTA CoinPower types
+
form factors

2019
Production
+
Massive Investments in production in lithium ion cells in Ellwangen and Noerdlingen

VARTA has a long history in research, development, and mass production of a variety of electro-chemistry and battery systems.

Batteries 101
VARTA

VARTA's Family Cells & Batteries:

- Voltages 1.5V to 48V
- Capacities 10mAh to >1500Ah
- Multiple Chemistry Options
- Coin & Cylindrical Sizes
- Pouch & Prismatic Sizes
- Embedded Battery Packs
- Consumer Removable Packs
- Industrial, Mobile Robotics Batteries
- Custom Designed Batteries
- Application Specific Standard Batteries

Cells

Easy Block/Blade/Pro

CellPac LITE

EasyPack

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Batteries 101: Battery B-I-N-G-O

B Battery	I Innovations	N Never	G Get	O Old
BMS Battery Management System	**18650** 18 mm x 65 mm Cell	**Cathode** Positive side of Cell	**Pb-A** Lead-Acid	**IEC 62133** Battery Certification
C-Rate 1 Hour Discharge Rate	**LCO** Lithium Cobalt Oxide (Li-Ion)	**Anode** Negative side of Cell	**NCA** Nickel Cobalt Aluminum (Li-Ion)	**26650** 26 mm x 65 mm Cell
Si-A Silicon Anode	**EODV** End-of-Discharge Voltage	VARTA	**Whrs** Watt-hours (V x Ah)	**UN38.3** Air Shipment Regulation
1642 UL Standard (Cell)	**NMC** Nickel Manganese Cobalt (Li-Ion)	**CC-CV** Constant-Current, Constant Voltage	**PCM/PCB** Printed Circuit Module/Board	**LFP** Lithium Iron Phosphate
103450 10 x 34 x 50mm Cell	**1Sx2P** 1 Series Cell & 2 Parallel Cells	**NiMH** Nickel Metal Hydride	**21700** 21mm x 70mm Cell	**BLE** Bluetooth Low Energy

Lunch & Learn

Batteries 101

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https://

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