Neue Fahrzeugkonzepte mit dem Fokus Nachhaltigkeit: Lithium-Ionen-Batterien für Elektrofahrzeuge

14. Zulieferforum der Arbeitsgemeinschaft Zulieferindustrie

26. Januar 2010 · Frankfurt

Dr. Jörg Kümpers
Johnson Controls Saft Advanced Power Solutions GmbH

Agenda

Neue Fahrzeugkonzepte:
Lithium-Ionen-Batterien für Elektrofahrzeuge

- **Elektrofahrzeuganwendungen: Vom Hybrid zum Elektroauto**
- **Schlüsselfaktoren fortschrittlicher Batterietechnologien**
- **Aktuelle Trends bei der Entwicklung von Lithium-Ionen-Batterien**

Johnson Controls – Global Footprint
Global Technology Centers for Development and Manufacturing

Nersac, France
NiMH & Li-Ion production

Bordeaux, France
Li-Ion Pilot Line & Research

Hannover, Germany
System Integration

Milwaukee, US
Li-Ion Lab

Cergy, France
BMS NiMH & Li-Ion

Global Capabilities

- Product Planning
- Benchmarking
- Consumer Research
- Design Studio
- Advanced Engineering
- Project Management
- Quality Systems
- Purchasing
- Product Development
- Prototype Shop
- Chemical Labs
- Testing
- Production Process/Prove Out
- Manufacturing

Shanghai, PRC
Development Facility

Johnson Controls SAFT – Global Footprint
Global Technology Centers for Development and Manufacturing

Nersac, France
NiMH & Li-Ion
production

JCS started Li-Ion Cell Production for Automotive Applications in Nersac, France in January 2008

Johnson Controls SAFT – Global Footprint – Manufacturing

Holland, Michigan
USA
Li-Ion production

Johnson Controls-Saft announced plans to build its first U.S. cell manufacturing facility for lithium-ion hybrid batteries in Holland, Michigan

- The plant will start production in 2011
- Investment to the Holland, Mich., facility is app $220 million.
- Initial capacity of 15 million lithium-ion cells.

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There are Multiple Types of Hybrids

Micro HEV *(a.k.a Stop/Start)*

- Low voltage
- Shuts down engine at idle to save fuel
- Example: BMW 1,3 mini series – JCI is the world leader in AGM micro hybrid batteries

Mild HEV

- Low to medium voltage
- Includes stop-start, regeneration braking and acceleration assist
- Example: Saturn Vue, S-class, 7-series

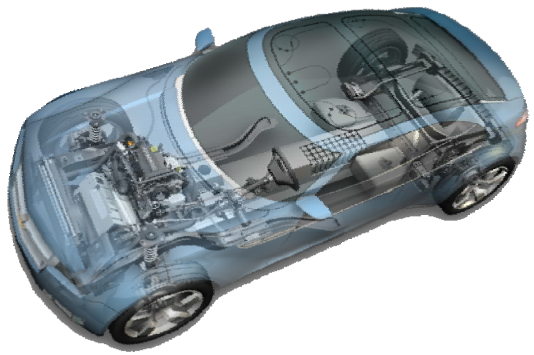
Full HEV

- High voltage
- Includes all mild HEV features PLUS electric-only operating range and optionally, multiple axle electric drive
- Example: Ford Escape, Toyota Prius

There are Multiple Types of Hybrids

Plug-In Hybrid (PHEV)

- High voltage
- Includes all full hybrid features PLUS
  electric-only operation for ~20 miles
- Ability to recharge battery through 120V electrical outlet
  (in addition to regenerative braking)
- Demonstration vehicles: GM Saturn VUE, Dodge Transit, Ford Escape



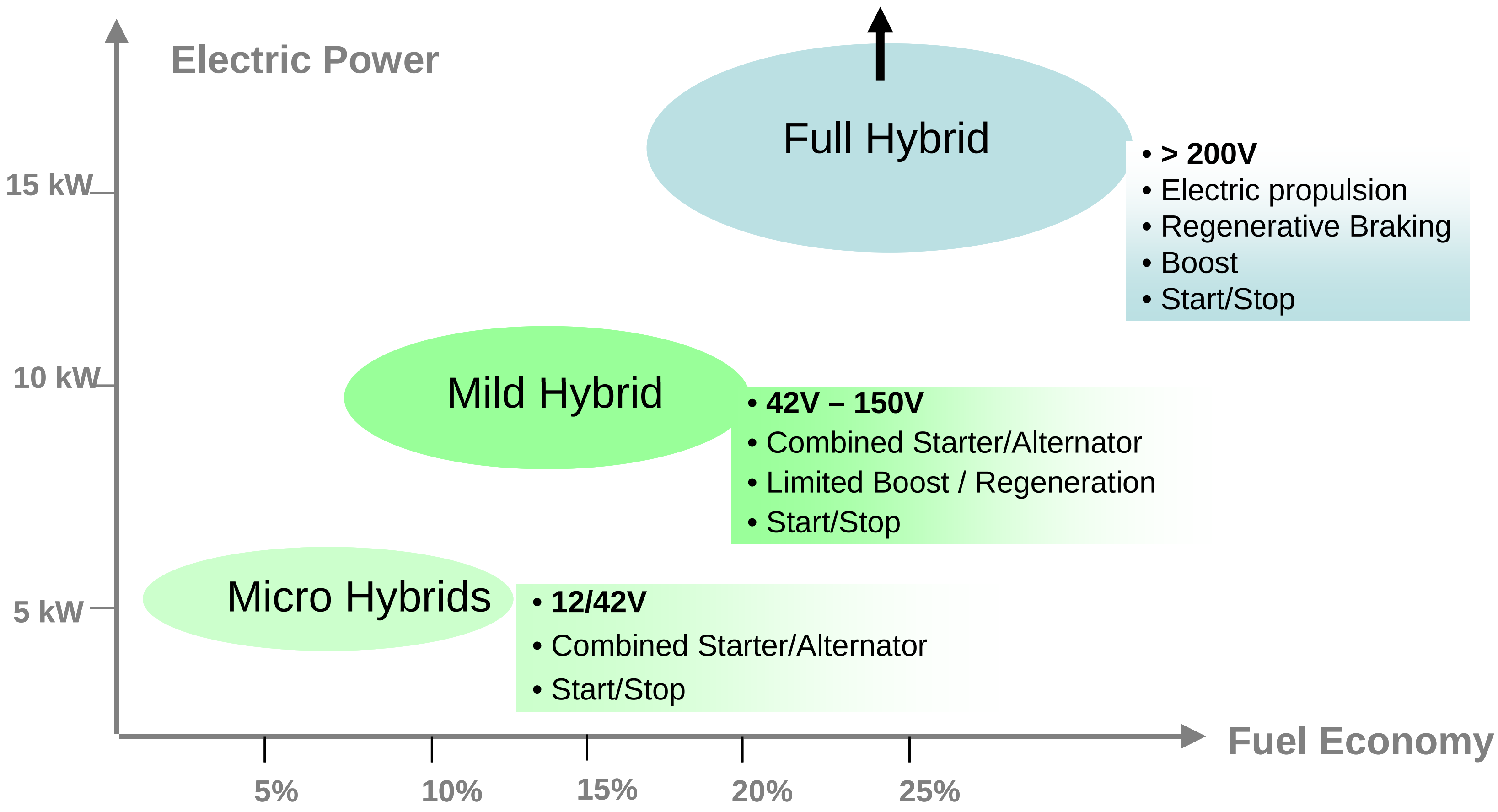
Electric Vehicle (EV)

- High voltage
- No internal combustion engine
- Recharge battery through 120V electrical outlet
- Demonstration vehicles : Mitsubishi i-EV

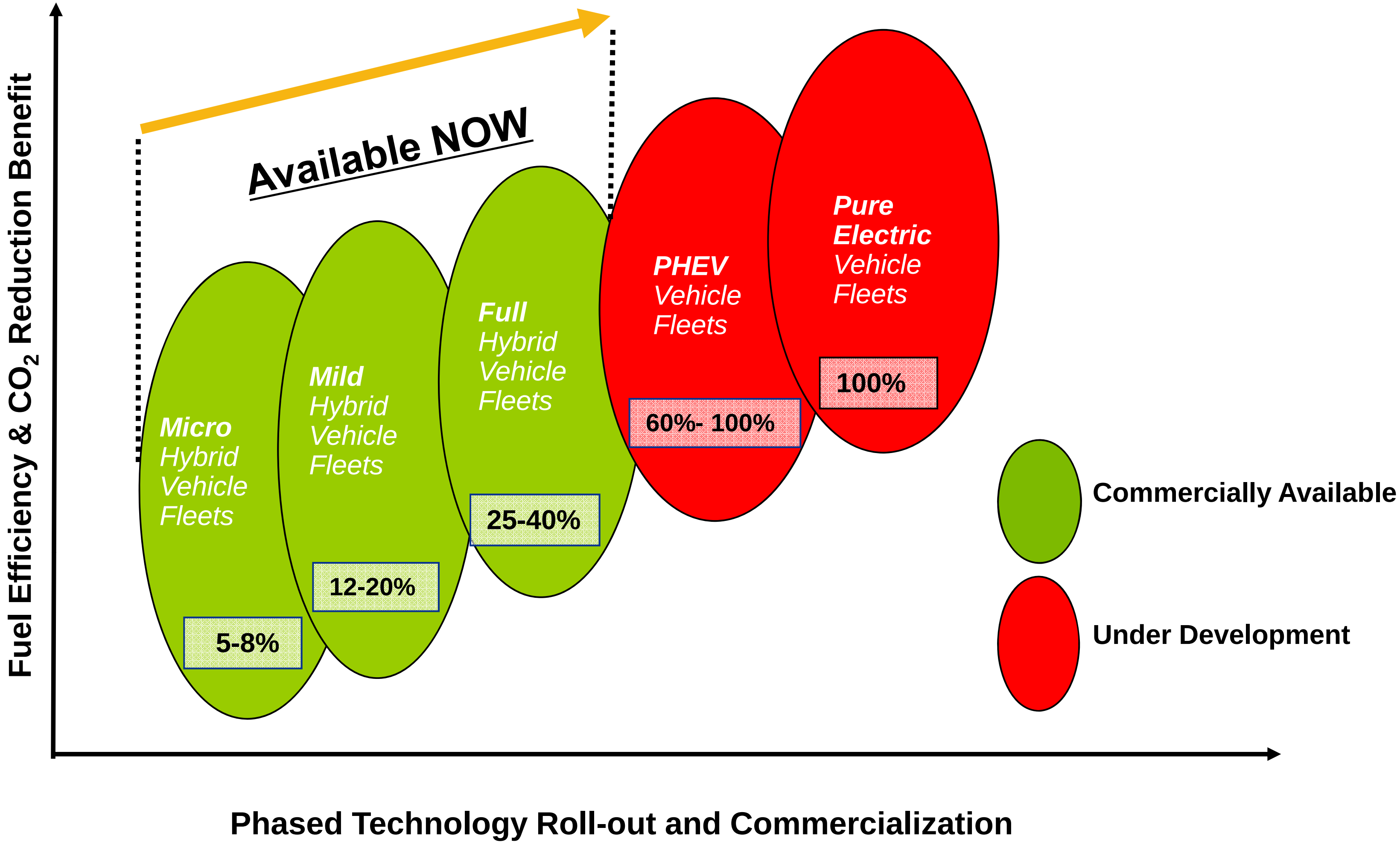
Fuel Cells

- High Voltage
- No internal combustion engine
- Full gas hybrid functionality
- Demonstration vehicles: Daimler, Ford, Honda, Toyota, GM

Fuel Economy can be enhanced by increasing electric Power



Battery Innovation “fuels” the Drive to sustainable Transportation



Li-Ion Battery Automotive Commercialization

- Li-Ion Technology in series production:

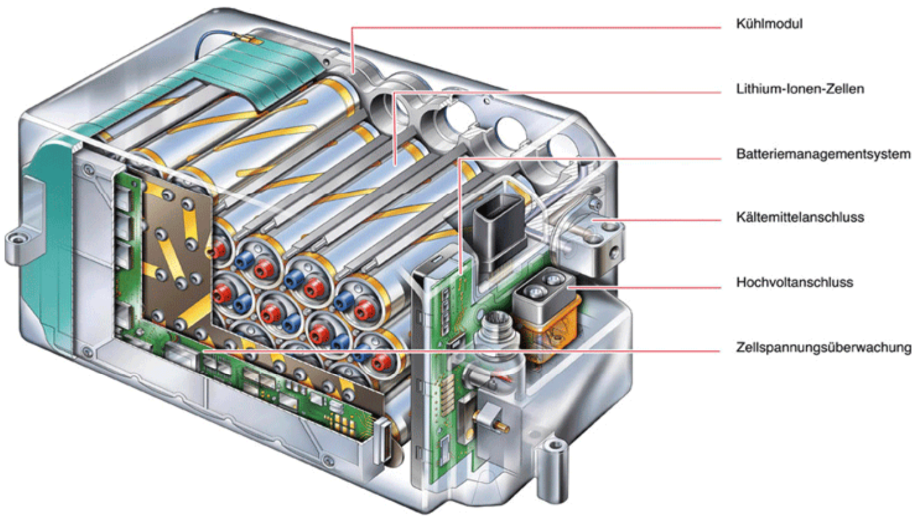
Vehicle	SoP	Type	Battery súpplier
Mercedes S-Class hybrid,	SoP 2009	Mild - HEV	Johnson Controls Saft / Conti
GM Volt – Plug In Hybrid	SoP 2010	PHEV	CPI / LG chem
Mitsubishi i-MiEV	SoP 2010	EV	GS Yuasa
BMW 7 Series ActiveHybrid	SoP 2010	Mild-HEV	Johnson Controls Saft / Conti
Nissan LEAF	SoP 2010	EV	AESC
BYD	SoP 2010	PHEV	BYD
Toyota Prius Plug-In	SoP 2010	PHEV	PEVE
Azure Dynamic's Balance HEV	SoP 2010	HEV	Johnson Controls Saft
Ford's first PHEV	SoP 2012	PHEV	Johnson Controls Saft



Li-Ion for Mild Hybrid Application – Example Daimler S-class :

New S-class S400 Blue-hybrid with JCS Li-Ion technology

- Mild Hybrid Battery System (19 kW boost)
    - Boost, Recuperation, Stop-Start, (no EV mode)
    - 35 cells each 6.5 Ah
- SoP in 2009 (MY 2010)
- Cooperation : Daimler / Continental / JCS
- Battery located in Engine Compartment : A/C – cooled



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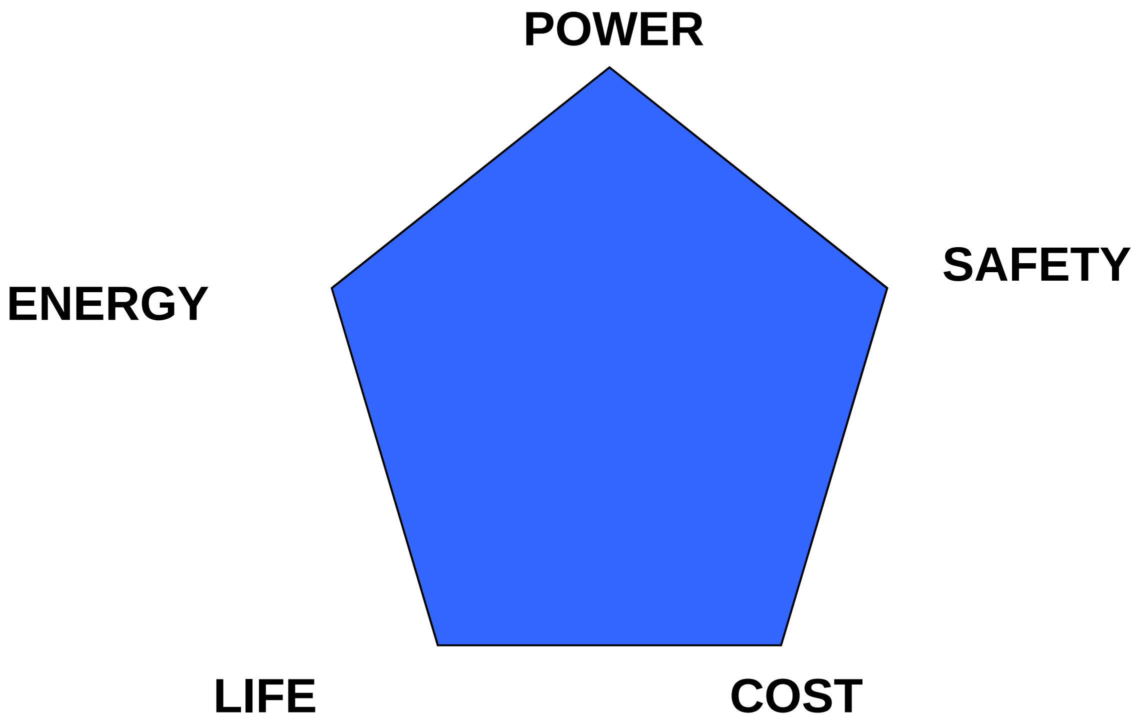
The Pentagon of Virtues displays the main parameters of an automotive battery for advanced automotive applications



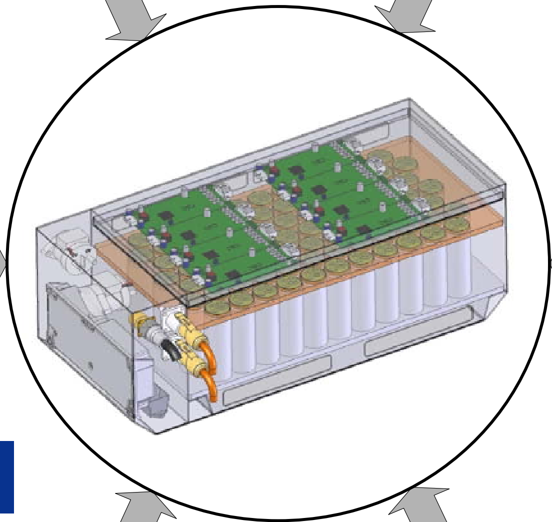
The Battery for automotive Applications is a complex System

Mechanical Subsystem

Electrochemistry/Cell

Cell Manufacturing

Electronics



Software

System Assembly

Electrical Subsystem

Thermal Management Subsystem

Design ⇔ System Characteristics

Design:

-Cell Type

- Number of Cells

- Architecture

- Cooling System

- Electronics

- Housing

Characteristics:

-Size / Dimensions / Volume

- Weight

- Energy Content

- Power capability

- Life Expectance

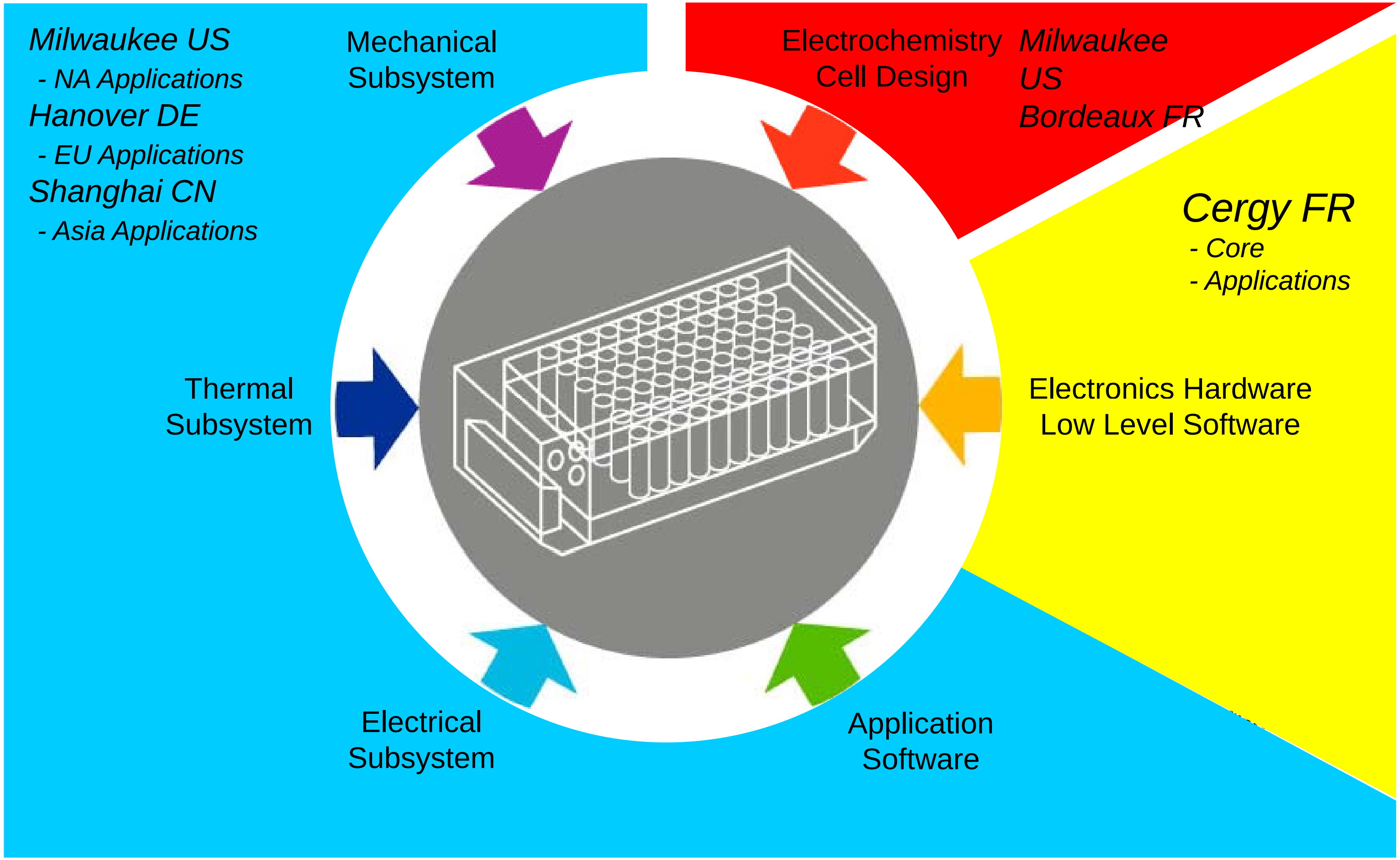
- Robustness

- Vehicle Integration

- Safety Level

JCS Technology Scope

S. Suckow, 19.06.2009



Energy of Battery Systems is strongly related to the chemical Energy

The laws of nature have fixed limits to specific energy of electrochemical systems from the periodic table of elements

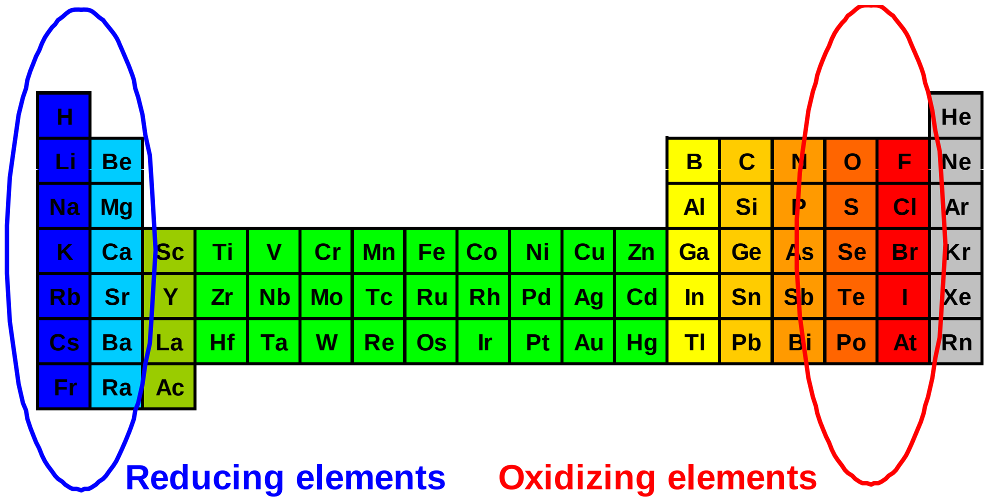
Li-Ion battery technology offers low weight, high reduction potential chemistry.

- High voltage due to high chemical energy:

$$U^{o} = -\frac{\Delta G}{n \cdot F}$$

- Low weight of Lithium metal

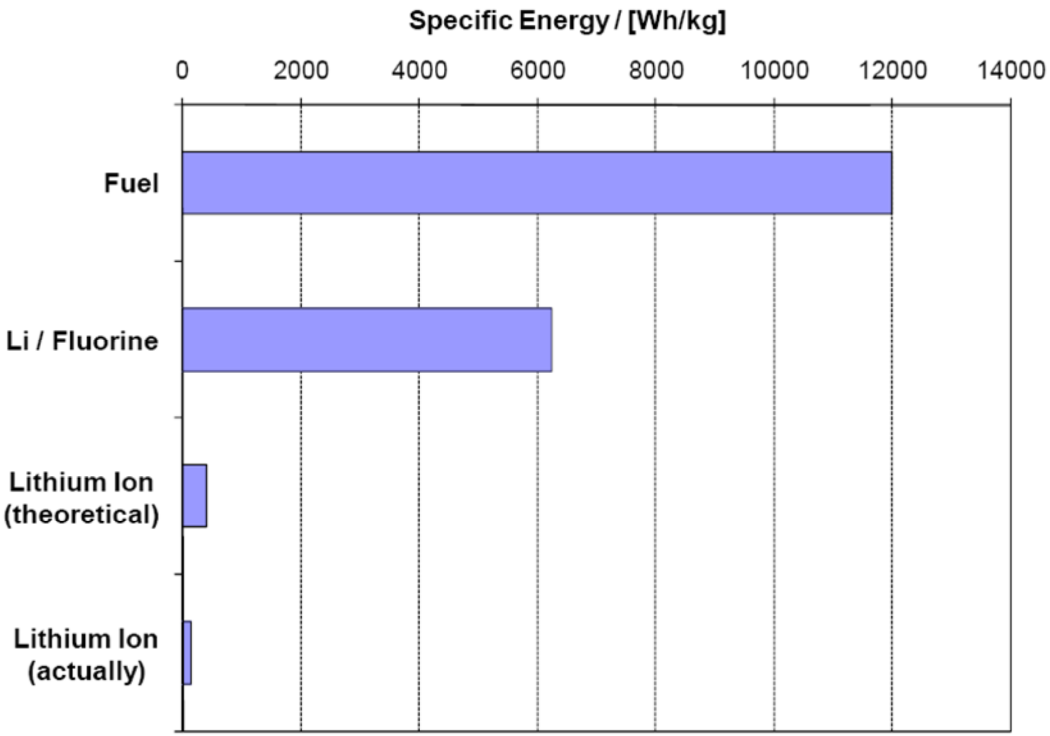
- High mobility of Li-Ions in solid state materials



Maximum theoretical specific energy is reached for the Li/F pair**: 6085 Wh/kg**

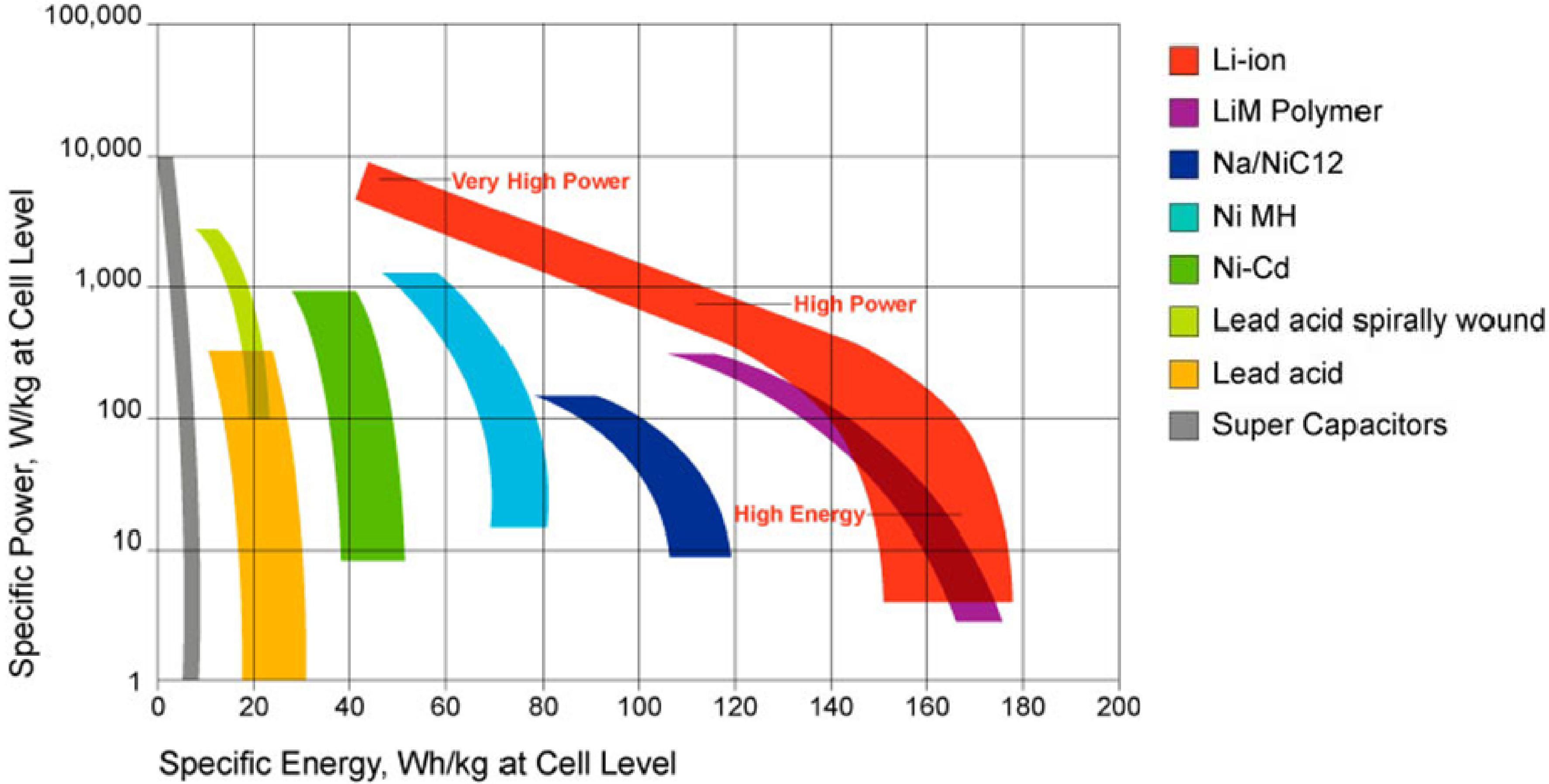
Battery Technologies: Specific energy of (electro)chemical storage

In practice only a small part of theoretical energy can be realized for rechargeable battery applications



	Ah/kg	U/V	Wh/kg
$Li//O_2$	1.787	4,27	7.630
$Mg//O_2$	1.330	3,61	4.801
$Zn//O_2$	659	1,65	1.318
$Li//S_x$	1.165	2,56	2.982
$C_6//LiMO_2$	170	4,20	714

Battery Technologies: Comparison of various Technologies



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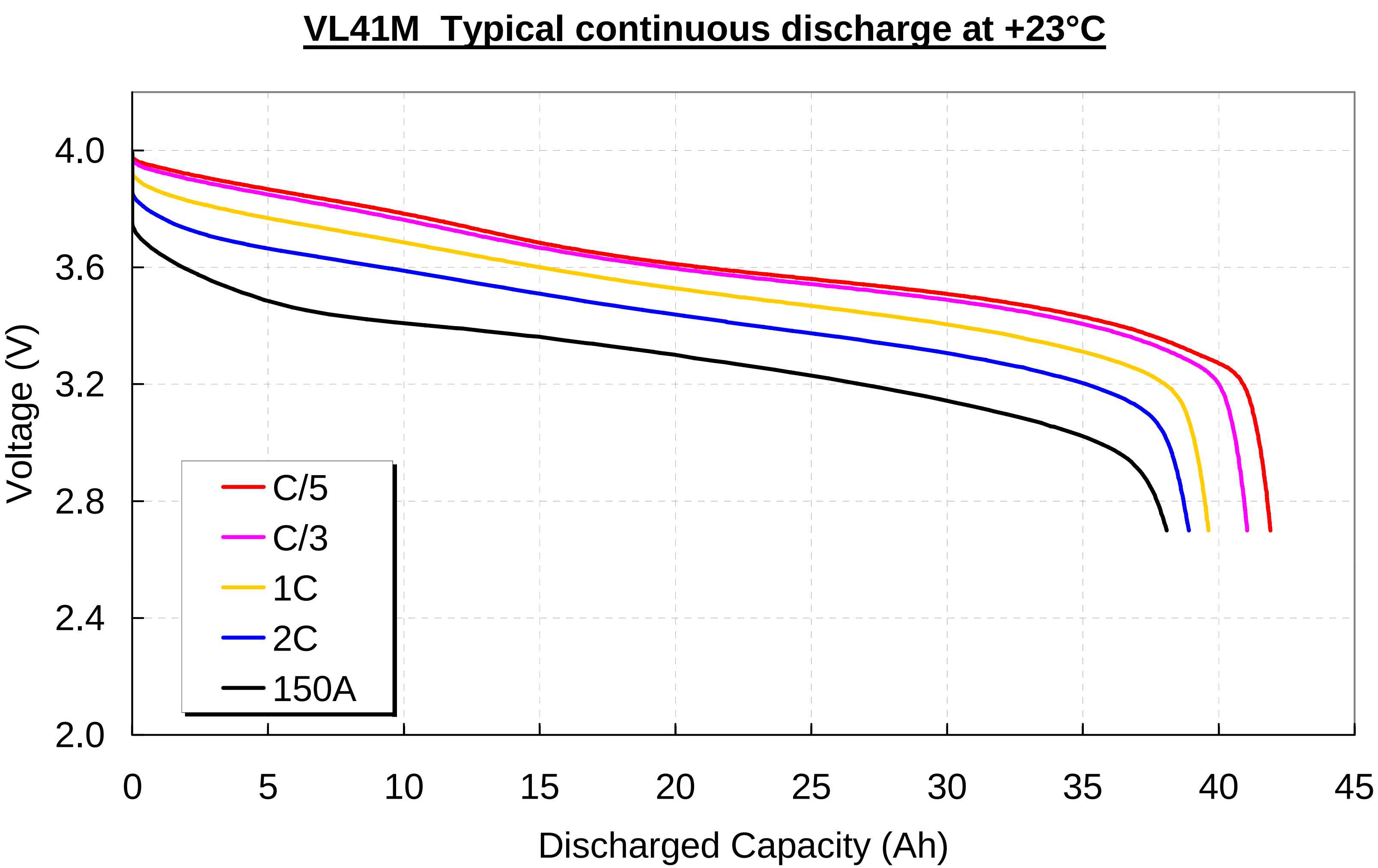
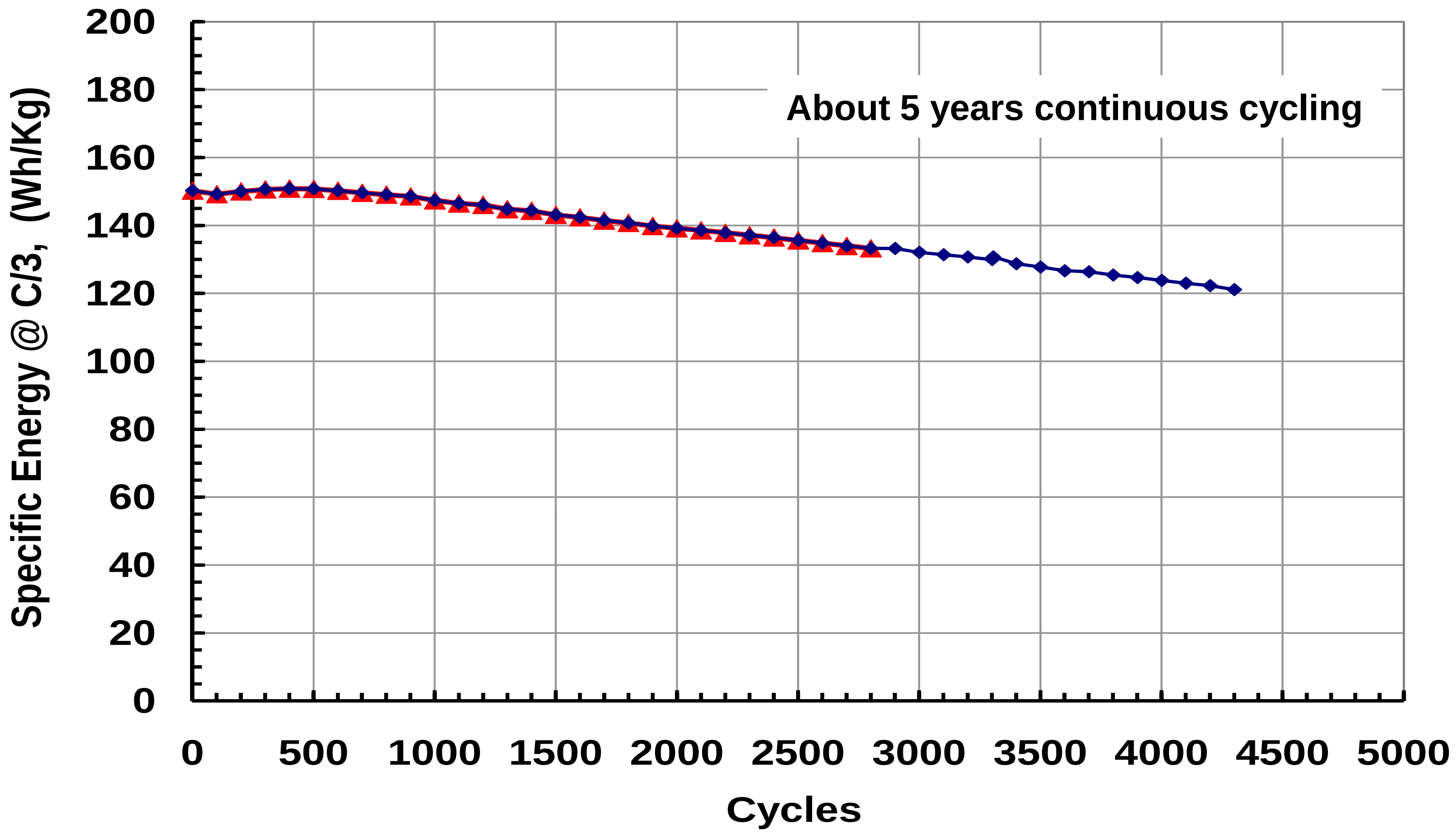
Battery Technologies: Voltage Characteristics



Battery Technologies: Cycle Life

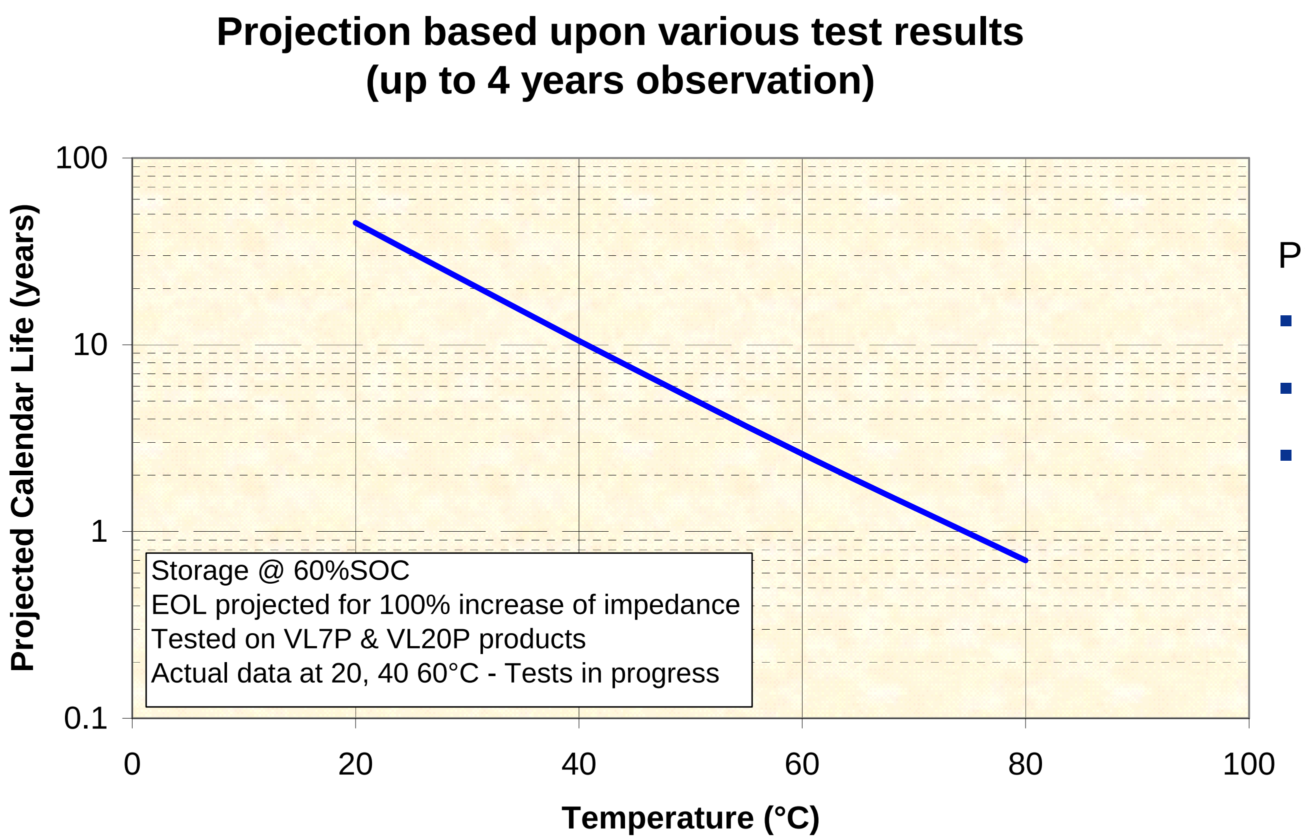
VL45E (High Energy) cells @ C/3 during 80%DOD (DST) cycling



Life Projection of Lithium Ion Batteries

Cycle Life Expectancy for Li-Ion Batteries:

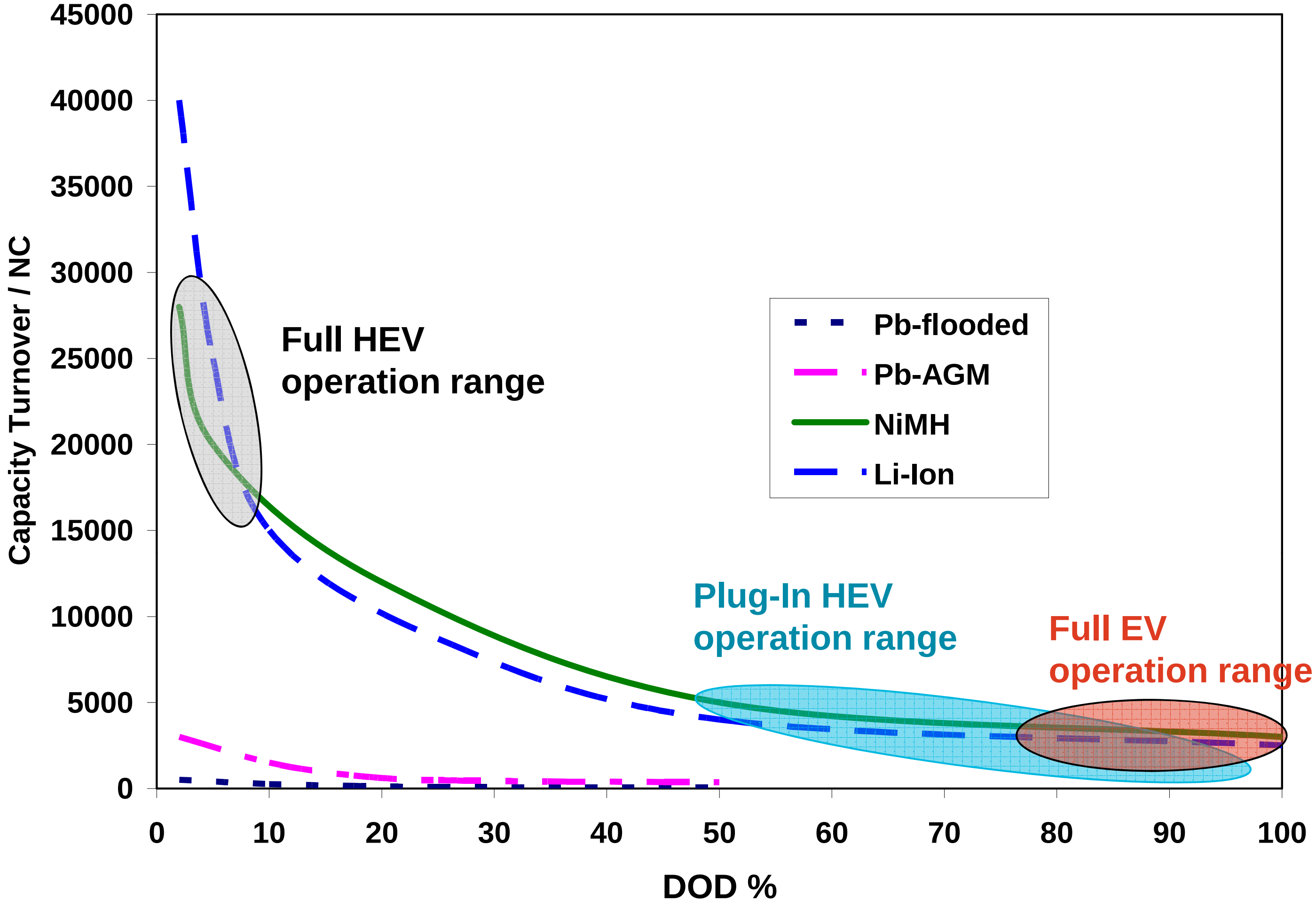
Arrhenius plots based on 100% increase of resistance:



Projection:

- 20 years life at 30°C
- 10 years life at 40°C
- 2.7 years life at 60°C

Energy Throughput is a key Parameter of Battery Technologies



Li-Ion is a Enabling Technology for the next Generation of HEVs

Li-Ion Battery Technology Advantages for HEVs

Nickel Metal Hydride is today's battery technology

Li-Ion is the target of every OEM as the obvious next step battery solution

WHY? {

30% Smaller	**50% Lighter**	**More Powerful**
Faster Recharge	**Enhanced Cycle Life**	**More Energy**

JCI is committed to support of R&D activities along the entire chain

•Basic research → •Applied research → •Development → •Production

•Electrochemistry

•Materials Discovery

•Energy Storage

•Cathode

•Anode

•Separator

•Electrolyte

•Other (Inerts)

•Cell

•Fuel Cells, Caps

•Energy

•Life

•Safety

•Cost

•Cell

•Mass production

•Scale Up

Continuous feedback of market needs and technology possibilities

Lithium Ion Cells for various Applications

Electrochemistry

- Li-Ion cells
- Positive material: NCA
- Negative material: Graphite
- Electrolyte: blend of solvent with dissolved $LiPF_6$

Construction

- Cylindrical, spiral wound type
- Aluminum case
- Can to cover assembly through laser welding
- 2 Terminals located at the same end
- Safety Features
- Overpressure release through rupture area
- Integrated current interrupt

JCS Li-ion Cell Products – PHEV and EV

Diameter 54 mm / Energy-Power Applications EV or PHEV

	VL45E	VL41M	VL22M	VL30P
Capacity (Ah) C/3 @ 4V	45	41	22	30
Dia. (mm)	54	54	54	54
Length (mm)	222	222	145	222
Weight (kg)	1.07	1.07	0.65	1.1
Volume (dm^3)	0.51	0.51	0.33	0.51
Energy (Wh)	160	146	78	107
Power (W) Current limit (A)	710 250	850 300	700 300	1520 500
Power (W) V limit, 2.5 V				2300
	30s – 50%SOC			10s – 50%SOC

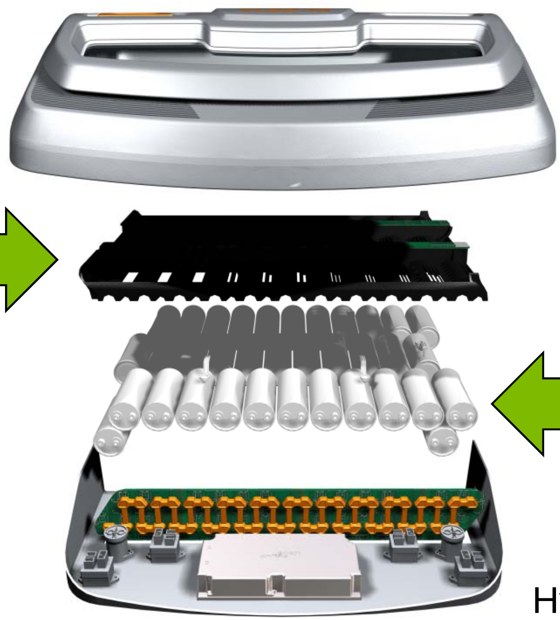
- Standard mechanical parts
- Standard chemistry (NCA/Graphite)
- Standard assembly processes
- Flexible height to various capacities
- 3 different electrodes types “E” / “M” / “P” for various Power to Energy ratios

- Note: characteristics at 25°C

JCS Battery System – Internal Perspective

Mechanical & Electrical Integration
- Communications Interfaces
- Packaging
- High Voltage Connectors
- Power Interface

Thermal Management
- Air Cooled
- Liquid Cooled



Cells and Cell Modules
- Li-Ion (Lithium-Ion)
- NiMH (Nickel Metal Hydride)

Hybrid System Electronics
- BMS (Battery Management System)
- CSC (Cell Supervisory Controller)
- Software
- Electronics
- Power Interface
- Electrical System

Thank you for your attention !

Vielen Dank für Ihre Aufmerksamkeit !

In case of questions / Bei Rückfragen

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