LG Chem's Current and Future Battery Technologies for xEVs

SAE 2018 Hybrid & Electric Vehicle Technologies Symposium

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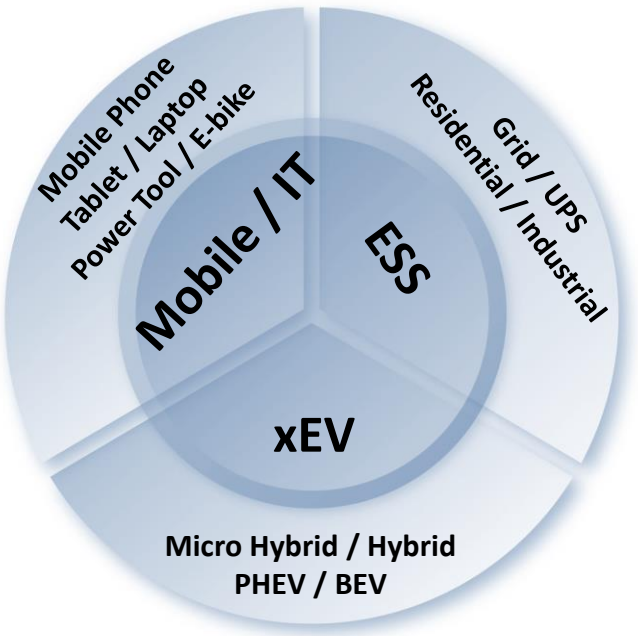
LG Chem Power Inc.

LG Chem Battery Business

LG Chem provides reliable energy solutions for Mobile/IT, ESS & xEV applications

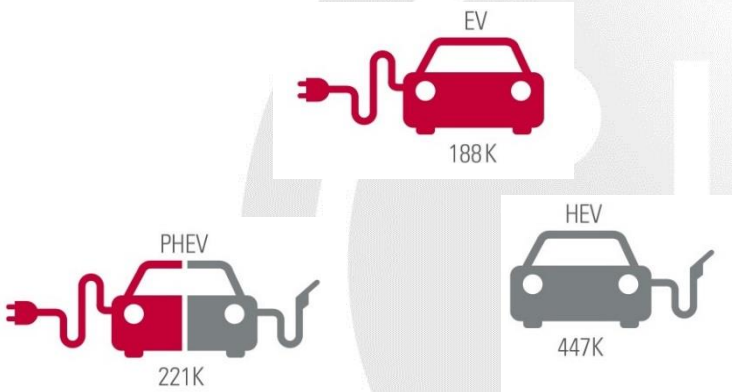
LG Chem Battery Business



Automotive Battery

Since 2009, more than 855K xEVS have been in the field with no safety issue

(Total: 115M Cells)



LG Chem Battery Global Operation

4 battery production plants and 3 R&D centers

Production Capacity: > 50 GWh by 2020

US FACILITIES

Troy, Michigan

- NA Tech Center with an engineering footprint for design of modules, packs, thermal management, and BMS.
- Sales, Marketing, and Field Support for both automotive and Energy Storage (ESS) business.

Holland, Michigan

- Manufacturing plant for cells, modules and packs
  - 5 models of cells
  - 2 models of modules
  - 2 models of packs

- **Battery pack technology: design and development**
- **Battery management systems (BMS)**
- **System integration, validation , and test support**
- **Program management**
- **Warranty Analysis**
- **Prototypes and production solutions**

ELECTRIC VEHICLES

Policy, Auto OEM's Strategy

Government Policy

⊖ Subsidy, ⊜ Environmental Regulations, ⊛ Mandatory EV Production Rules

- Banning ICE Cars : Norway/Netherland(2025), U.K./France(2040), Germany(2030, Resolution passed), China(Under consideration)

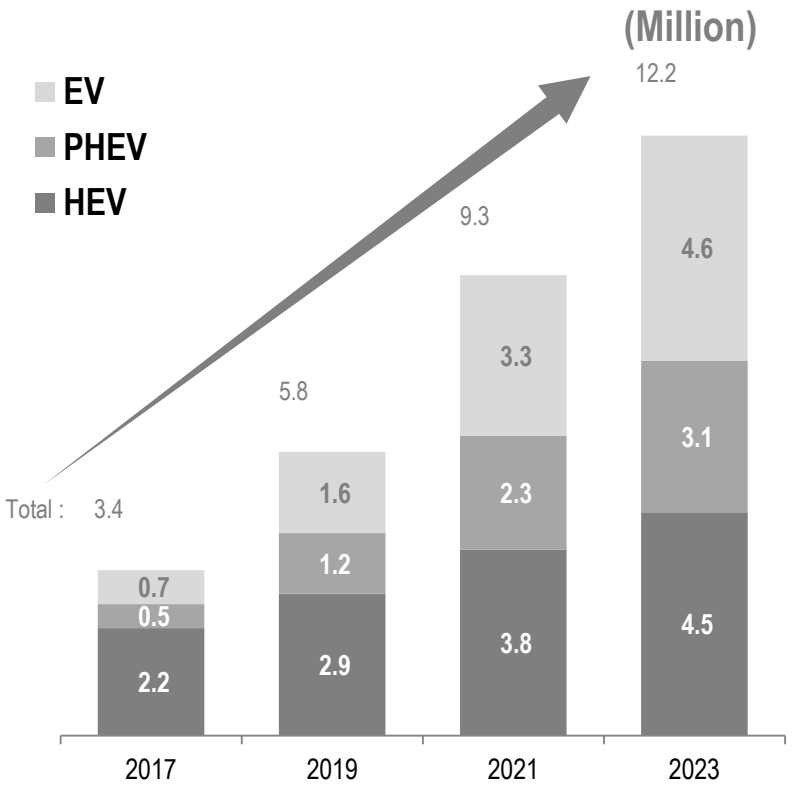
Auto OEM's Strategy

- VOLVO: All cars to be electric or hybrid from 2019
- Ford: 40 electrified vehicles by 2022. 16 EVs. $11B investment
- GM: 20 new BEVs + FC by 2023
- VW: All models to be electrified by 2030. Plans to invest $40B
- BMW: 12 full electric cars and 13 hybrids to market by 2025
- Mercedes: 10 new electric car models to market by 2022
- Toyota: 50% of all vehicles will be electrified by 2030. Overall strategy region specific. 4.5M cars hybrid/PHEV, 1M EV/FC by 2030

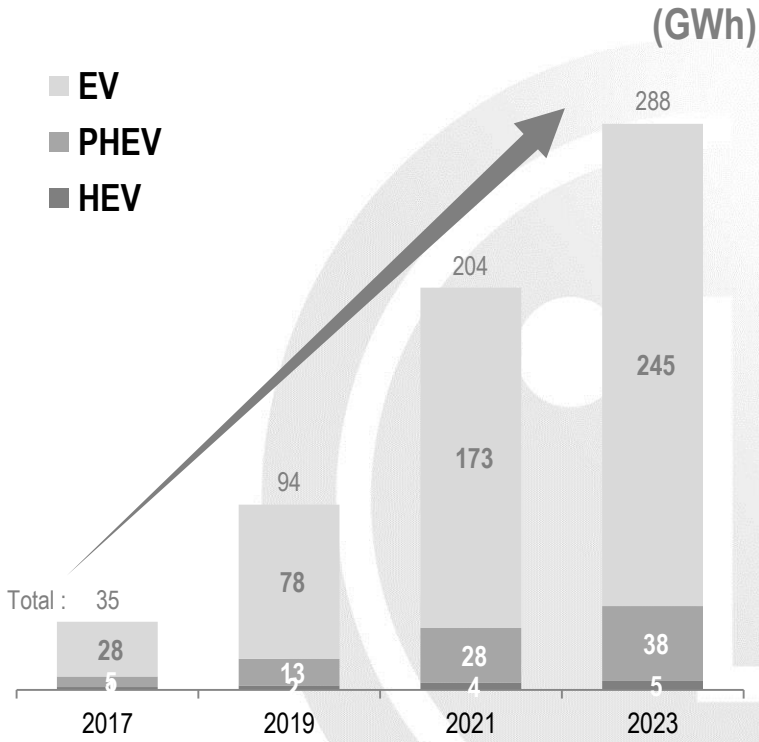
Global xEV Market

- **Global xEV Market is expected to grow at a rapid pace in coming years**
- **EV battery demand will lead market growth in terms of battery capacity (~ 80%)**

Market Forecast (Unit)

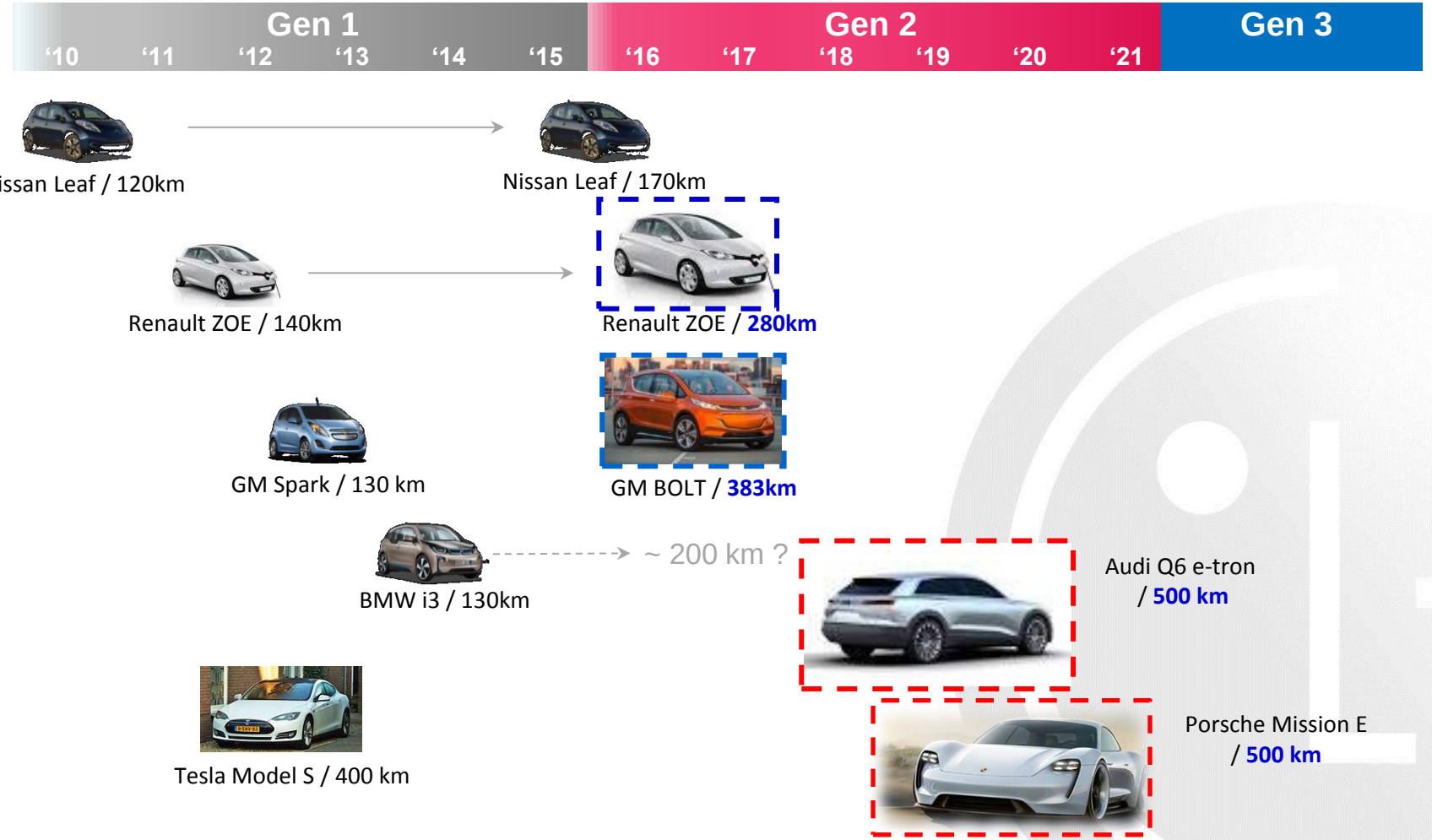


Market Forecast (Capacity)



Global EV Vehicle

EVs: variety of ranges in the market or soon to be introduced



Key Challenges for Future EV Battery Development

- **Driving Range Extension**
  - 300 miles
- **Affordable Vehicle Price**
  - $ 100/kWh cell
  - $125 pack
- **Quick Charging**
  - 80% SOC in 20 min
- **Reuse and Recycle**

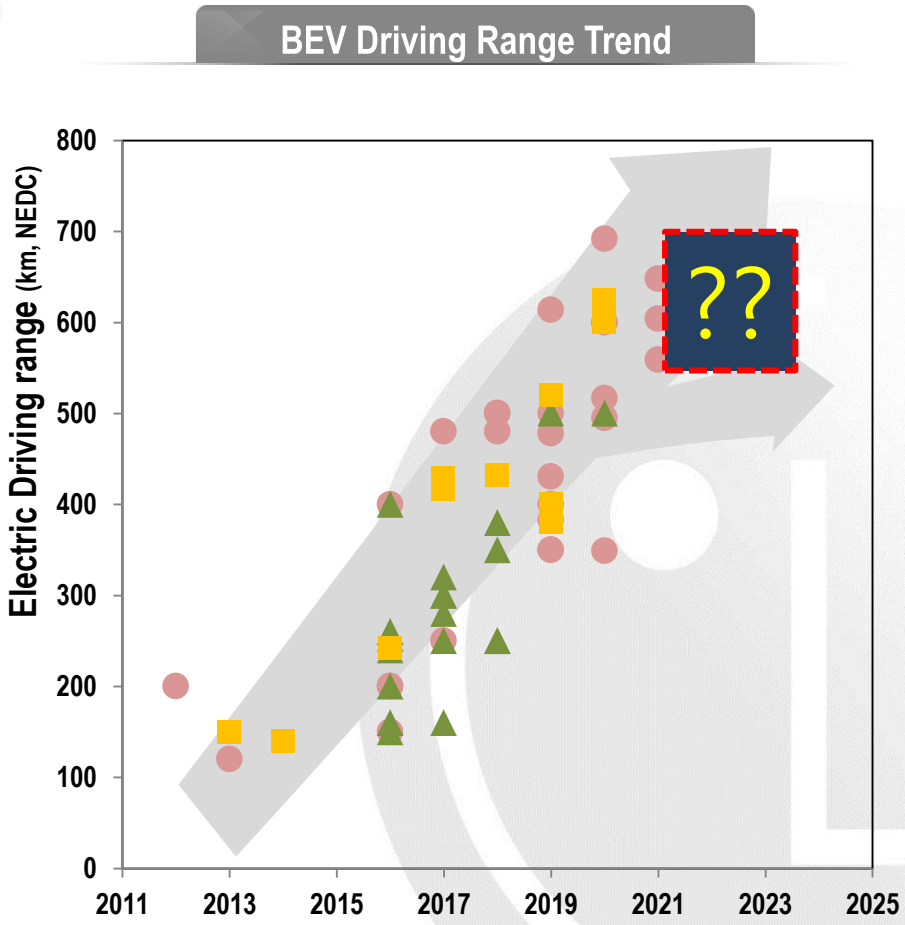
- **Energy Density Increase**
  - 750 Wh/l; 350 Wh/kg (’22)

  High energy cathode, Silicon in the anode
- **Cost Reduction**
  - *Material innovation, simpler pack design, thermally robust chemistry; minimum cooling requirements*
- **Charge Power Improvement**
  - *Multi-step charging*
  - *Electrode resistance reduction by coating, doping*

Driving Range Extension vs. Energy Density Increase

What should the final driving range target be?

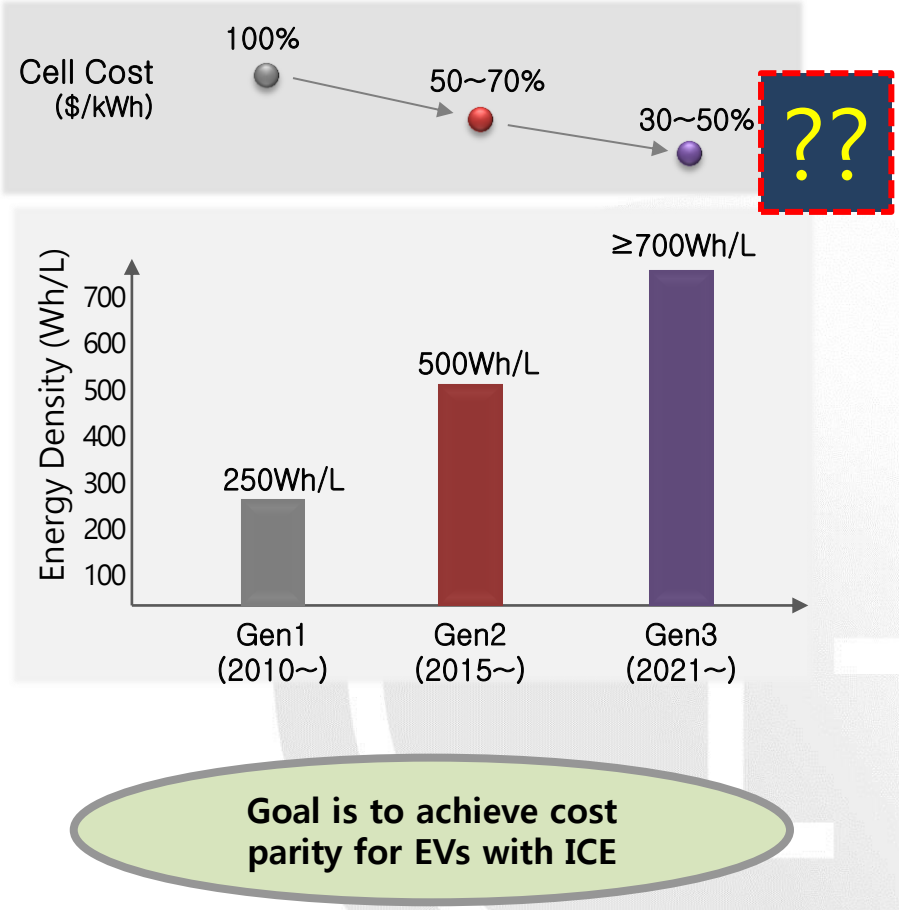
- Current ICE driving range ~ 500 - 800 km
- Current EV driving range ~ 300 - 500 km
- Need further improvement in energy density to ensure actual driving range over 500 km at low temp and when HVAC is in use.



Cost Reduction in Vehicle vs. Battery

How much more can the battery cost be reduced?

- Current material cost of EV battery is ~ 60~80% depending on design
- Metal (Lithium, Cobalt etc.) prices have placed uncertainty on future battery price direction
- Other factors to consider: *Manufacturing, Pack, BMS, Driving range, Fuel Efficiency*

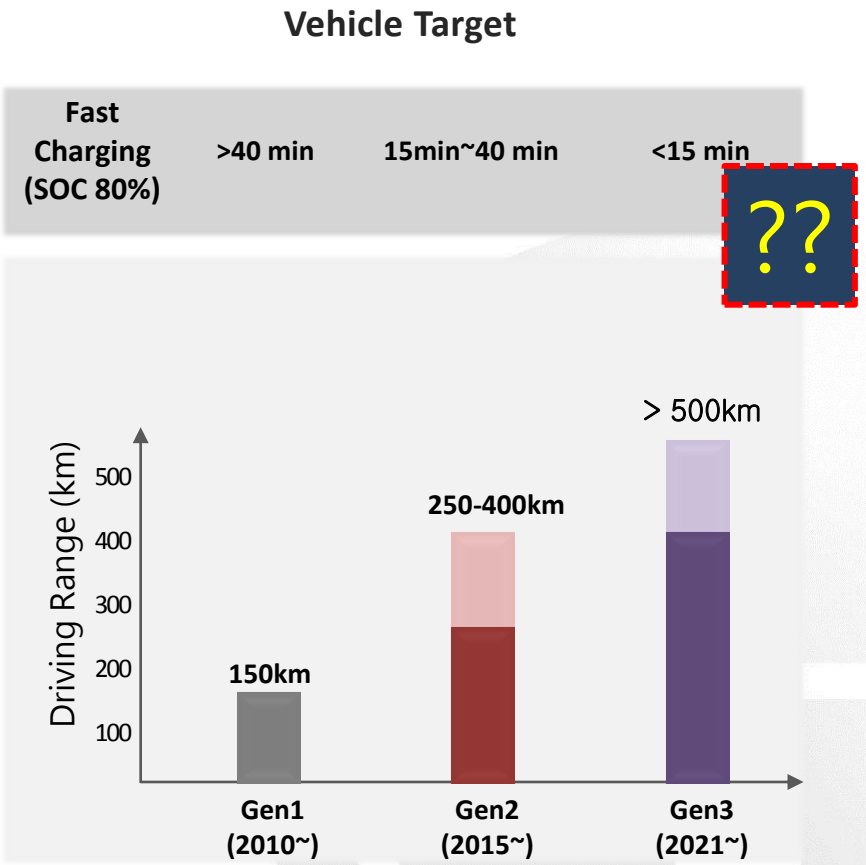


Fast Charging

How quick? How much EV range?

- Current EVs can be fast charged within 15~40 min for ~ 80% of original driving range
- Fast charging capability is inversely proportional to energy density
- Charging infrastructure needed to support fast charge (50~100 kW now)

Time : < ?? Min
Range : > ??? km
Charging Station



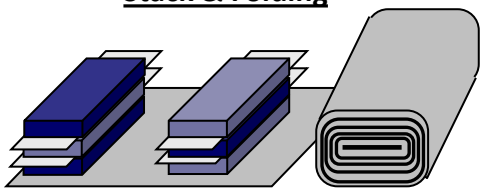
LG CHEM CELL TECHNOLOGY

Large-format pouch cells championed by LG Chem provide packaging flexibility that is a design advantage for automotive batteries.

High Energy Density

- **Our DNA is chemicals and materials**
  - In-house capability for cathodes, anodes, electrolytes, and separators
- **Stack & Folding structure**
  - Stack & folding cell design allows uniform distribution of heat and stress

Stack & Folding



- **Volumetric Energy Density**
  - Higher utilization of available space for active electrodes

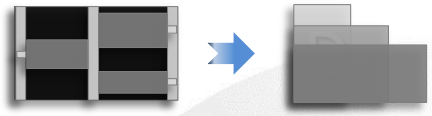
	μ-HEV	HEV	PHEV	EV
Capacity	4~ 20Ah	5~7Ah	26~50 Ah	37~70Ah

Design Flexibility

- Pouch cells offer footprint flexibility to match vehicle package

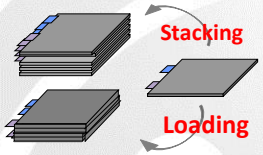
Electrode

Size variation



Assembly

Stack "count" & tab direction variation



Cell

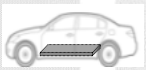
Various cell products

Pack

Compact configuration for limited available space

μ-HEV

Minimize pack height by adjusting cell stacks

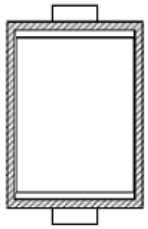
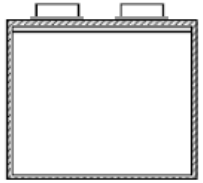
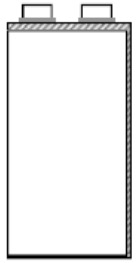
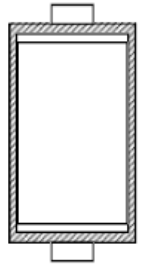
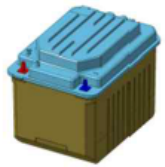
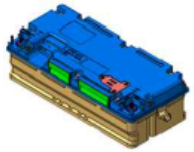


EV

Locate pack under frame by minimizing cell height

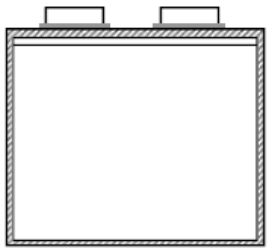
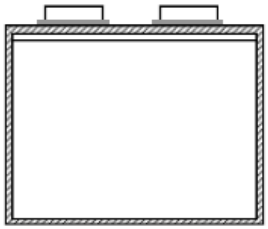
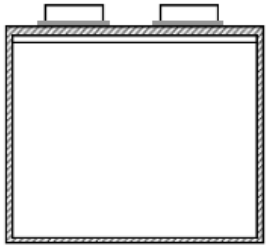
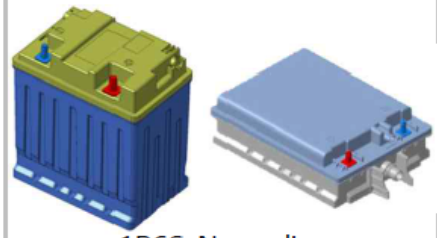
LiB for 48V Application

LiB for 48V Application: LGC's Current Line-up for affordable 48V

Cell	Chemistry	NCM/LTO		NCM/Graphite	
	Chemistry Generation	Gen 1	Gen 2	Gen2	Gen2
	Sample Stage (SOP)	Mass Production ('17 2Q)	C sample ('19 2Q)	Mass Production ('16 1Q)	D sample ('17.4Q)
	Drawing	 W120 x L243 x T3.7	 W137.5 x L150 x T8.6	 W133 x L 312.5 x T4.05	 W112 x L 246.5 x T6.66
	Capacity	4.5 Ah	10Ah	9.5 Ah	9.8 Ah
	Energy Density	90 Wh/L	120 Wh/L	210 Wh/L	190Wh/L
	Discharge R (25°C, SOC50, 10s)	1.5 mΩ	0.70 mΩ	1.8 mΩ	1.6 mΩ
Pack	Drawing	 1P20S, Air Cooling W143.1 x L343.4 x H143	 1P20S, Liquid Cooling W175 x L242 x H199	 1P13S, Air Cooling W175 x L394 x H110	 1P12S, Air Cooling (DC/DC) W356 x L522 x H103

LiB for 12 V Application

LIB for 12V application : LGC's Current Line-up

Cell	Chemistry	NMC/LTO		LFP/Graphite
	Chemistry Generation	Gen 1.5	Gen 2	Gen1
	Sample Stage (SOP)	D sample ('18 2Q)	C sample ('19 2Q)	Mass Production ('17 2Q)
	Drawing	 W143 x L150 x T11	 W137.5 x L150 x T8.6	 W143 x L146.5 x T13.65
	Capacity	10 Ah	10Ah	20 Ah
	Energy Density	90 Wh/L	120 Wh/L	230 Wh/L
	Discharge Resistance (25°C, SOC50, 10s)	0.73 mΩ	0.70 mΩ	1.5 mΩ
Pack	Drawing	1P6S, No cooling W110 x L175 x H190	 1P6S, No cooling W110 x L175 x H190 (left) W180 x L240 x H70 (right)	 3P4S, No cooling W175 x L278 x H190 (LN3)

LG Chem
Power Inc.

Thank You!