# *The xEV Industry Insider Report*
## *December 2016*

# REPORT OUTLINE

## I. xEV Market Trends

### 1. Overview

- Current xEV Market Conditions
- xEV Market Direction: High Voltage
- xEV Market Direction: Low Voltage
- Market Drivers
- Market Drivers (2)
- Until Tesla, most automakers had introduced subcompact and city EVs with a 70- to 90-mile range

### 2. Vehicle Markets by Region

- U.S. Market – EV
- Aftermarket pricing for early EV-EREV is dropping fast…
- U.S. Market – PHEV and HEV
- European Market
- European Market (2)
- Powertrain Electrification and $CO_2$ Emission Impact
- European Market – Uncertainty for 2025
- Chinese Market – Government
- Chinese Market – Automakers
- Chinese Market – Battery Makers
- Chinese e-Bus Industry
- Chinese xEVs—the Bottom Line
- Japanese Market

## 3. Vehicle Market Forecast

- HEV Market by Vehicle Producer 2010 – 2020
- HEV Market by Vehicle Producer 2010 – 2020, Excluding Toyota and Honda
- HEV Market by Hybrid Category
- HEV Market by World Region 2009 to 2020
- EV Market Forecast
- PHEV Market by Producer
- EV Market Forecast by World Region
- PHEV Market Forecast by World Region

## 4. Directions of Individual Automakers

- xEV Efforts by Automakers—Asia
- xEV Efforts by Automakers—U.S. / Europe
- xEV Efforts by Automakers—Europe
- Toyota / Lexus
- 2001-16 Toyota HEV Family
- Volkswagen / Audi / Porsche (1)
- Volkswagen / Audi / Porsche (2)
- General Motors
- Ford
- Nissan
- Renault
- Honda
- BMW
- Hyundai
- Mitsubishi Motor Corporation (MMC)

- Fiat Chrysler Automobiles
- Daimler
- Volvo
- PSA Group
- Tesla Motors
- Tesla's Impact on Electric Vehicle Design
- Tesla's Impact of the EV/Battery Industry
- Chinese Producers
- Premium Brands: Jaguar, Land Rover & Others

## II. Lithium-Ion Battery Technology for xEVs

### 1. Key Design Parameters

- xEV Battery Technology Overview
- Historical xEV Battery Development
- Cathode Chemistry
- Electrolytes
- Cell Casing

### 2. HEV Batteries

- Batteries for Strong Hybrids
- 2001-16 Toyota HEV NiMH Battery Pack Parameters
- HEV Li-Ion Cell Design Matrix
- Li-Ion Prismatic Metal Can Cells Involved in Production HEVs
- Li-Ion HEV Cell Materials Cost
- Li-Ion HEV 5-Ah Cell Price
- HEV Battery Price Trends
- Li-Ion HEV: Key Cost Components
- Micro-2 Hybrids: Energy-Storage Solutions

- Micro-2 Hybrids: Energy-Storage Solutions (2)
- Micro-2 Hybrids: Energy-Storage Solutions (3)
- 48V Mild Hybrids – Battery Requirements and Selection
- Low-Voltage Hybrid Li-Ion Design

3. EV & PHEV Batteries

- Battery Pack Capacity for PHEVs
- PHEV Battery Pack – Specific Energy
- PHEV Battery Pack – Capacity vs. Launch Year
- PHEV Battery Pack – Specific Energy vs. Launch Year
- PHEV Cells on the 2015 Market
- PHEV-2 Roadmap
- Where is the improvement in energy density coming from?
- GM Volt 2/Volt 1 Battery Comparison
- Mercedes  PHEV Battery-Pack Parameters
- EV & PHEV Battery Life
- Li-Ion Cells Employed in EVs 2008-2016
- Key Characteristics of EV Cells Utilized in EV Packs Q4 2016
- EV Pack Key Characteristics
- Specific Energy of EV Battery Packs
- Battery Packs for EVs vs. Launch Year
- Battery Packs for EVs – Specific Energy vs. Launch Year
- Li-Ion Battery Safety
- Safety at Module and Pack Levels
- Safety: Key Issues
- Safety Enhancement and its Cost
- xEV Battery Power and Energy Level vs. Applications

- xEV Battery Energy Density vs. Power Level
- 37-Ah PHEV Cell Materials Cost
- 37-Ah PHEV Cell Price
- Cell Price for a 44 Ah Prismatic PHEV cell (2020)
- PHEV Battery Price Trends
- 56-Ah EV Pouch Cell Materials Cost
- 56-Ah EV Pouch Cell Price
- 3.4-Ah 18650 Cell Materials Cost
- 3.4-Ah 18650 Cell Price 2016
- 21700 Cell Materials Cost – 2020
- 21700 Cell Price 2018
- Nickel Metal below $11/kg – Much Below Average Pricing of the Last 5 Years
- EV Cell Pricing Chevy Bolt (GM)
- EV Battery Cost Estimate
- xEV Battery Technology Cost and Pricing
- EV Battery Price Trends

## III. xEV Battery Market Forecast to 2020

### 1. xEV Market Overview

- xEV Battery Market Overview
- xEV Battery Pack Business
- 2020 Automotive Li-Ion Battery Market
- xEV Li-Ion Battery Market 2020

2. HEV

    - HEV OEM – Supplier Relationships
    - HEV Battery Pack Market
    - Li-Ion HEV Battery Module Market

3. PHEV & EV

    - PHEV OEM – Supplier Relationships
    - PHEV Battery Cell Market by Producer (including PHEV Buses)
    - EV OEM – Supplier Relationships
    - EV Battery Cell Market by Producer
    - Combined PHEV & EV Cell Market by Producer

4. Demand for Materials

    - HEV Cell Materials Demand 2020
    - PHEV-EV Cell Materials Demand 2020
    - xEV Cell Materials Demand, 2020

## IV. Technology and Market Development to 2025

- Lithium-Ion Projections for 2025
- Beyond Li Ion in 2025
- Beyond Li Ion – Which technologies are promising?
- Battery Requirement Matrix Li Ion versus Li/S
- Our Projections for 2025 – EVs
- Our Projections for 2025 – PHEVs
- Our Projections for 2025 – Strong HEVs
- Our Projections for 2025 – 48V Mild HEVs
- Automotive Li-Ion Battery Business – 2025 Base Case
- Automotive Li-Ion Battery Business – 2025 Aggressive Case

## V. Directions of Individual Battery Makers

- Panasonic
- LG Chem
- Samsung SDI
- AESC Advanced Energy Supply Corporation
- GS Yuasa Group
- Toshiba
- Hitachi Vehicle Energy
- A123 Systems
- Johnson Controls
- SK Innovation
- CATL

## VI. Appendix

### 1. Levels of Vehicle Hybridization

- Levels of Vehicle Hybridization/Electrification
- Key Hybrid Functions
- Which level of electrification?
- Micro-1 Hybrids (Stop/Start)
- Micro-2 Hybrids
- 48V Mild Hybrids
- 100-140V Mild Hybrids
- Strong Hybrids
- Plug-in Hybrids
- History of EV Battery Development
- Electric Vehicles

- Fuel-Cell Vehicles
- Heavy-Duty Vehicles

2. Lead-Acid and NiMH HEV Batteries and Ultracapacitors
    - Enhanced  Flooded Lead-Acid Battery Design (Exide)
    - Valve-Regulated Lead Acid
    - Lead Acid in Future Automotive
    - EC Capacitors
    - Nickel Metal Hydride HEV Cells
    - Commercial Status of NiMH
    - Lead Acid Producers – U.S. & Europe
    - Lead Acid Producers – Japan
    - NiMH producers Primearth EV Energy