

# *The xEV Industry Insider Report*

## *November 2017*

### REPORT OUTLINE

#### I. xEV Market Trends

##### 1. Overview

- Market Drivers
- Recent EV-Market Boosters
- Until Tesla, most automakers had introduced subcompact and city EVs with a 70- to 90-mile range
- Battery-EV Main Development and Direction
- PHEV Main Development and Direction
- Strong HEV Main Development and Direction
- Mild to Advanced Micro-HEV (MHEV) Main Development and Direction
- Powertrain Electrification and CO2 Emission Impact
- xEV Market Development by Category

##### 2. Vehicle Markets by Region

- Current Chinese xEV Market Trends, Market Drivers – Government
- Current Chinese xEV Market Trends, Market Drivers – Automakers
- Chinese e-Bus Industry
- Chinese xEVs – The Bottom Line
- Current European xEV Market Trends – Market Drivers
- Current European xEV Market Trends – EVs
- Current European xEV Market Trends – PHEVs
- Current European xEV Market Trends – Strong Hybrids (HEVs)
- Current European xEV Market Trends – Mild Hybrids (MHEVs)
- Current European xEV Market Trends – Micro Hybrids ( $\mu$ HEVs)

- Current U.S. xEV Market Trends – Market Drivers
- Current U.S. xEV Market Trends – EVs
- Current U.S. xEV Market Trends – PHEVs
- Current U.S. xEV Market Trends – Strong HEVs
- Current U.S. xEV Market Trends – MHEVs
- U.S. HEV Sales
- Current Japanese xEV Market Trends – Hybrids
- Current Japanese xEV Market Trends – PHEVs/EVs
- Current xEV Market Trends – Rest of the World (ROW)

### 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
- EV Market Forecast – Excluding Chinese Automakers
- 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
- 2001-17 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. Mild and Strong Hybrid Batteries

- Batteries for Strong Hybrids
- 2001-17 Toyota HEV NiMH Battery Pack Parameters
- HEV Li-Ion Cell Current 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 Battery Technology and Cost

- 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 Cell and Pack – 2017 Market
- GM Volt 2/Volt 1 Battery Comparison
- PHEV-2 Roadmap
- Cells Delivering 600Wh/liter are Being Qualified
- VW's Aggressive Technology Roadmap – Very Challenging Beyond 700Wh/liter
- Where is the improvement in energy density coming from?

- 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 H1-2017
- EV Pack Key Characteristics since 1996
- Energy Density Evolution of Cylindrical Cells
- Specific Energy of EV Battery Packs
- Battery Packs for EVs vs. Launch Year
- Battery Packs for EVs – Specific Energy vs. Launch Year
- Tesla Battery Capacity versus Driven km (as published by Tesla Drivers Club)
- 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 2020
- Nickel Metal Pricing \$US/metric ton
- Cobalt Pricing \$US/metric ton
- Lithium Pricing
- NMC Cost Estimate 2017 to 2020 Average
- EV Cell Pricing Chevy Bolt (GM)
- EV Battery Cost Estimate, 2020
- EV Battery Price Trends
- VW's Aggressive (unrealistic) Price Target for Cells and Packs
- xEV Battery Technology Cost and Pricing

### 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. Mild and Strong Hybrids

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

#### 3. PHEVs & EVs

- 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

#### 1. xEV Market Development and Forecast by Region

- EV Market Development to 2025
- 2025 xEV Market Share Forecast by Region
- 2025 xEV Market Forecast by Region

#### 2. Battery Technology for 2025

- Lithium-Ion Technology Projections for 2025
- Beyond Lithium Ion in 2025
- Beyond Li Ion – Which Technologies are promising?
- Li Ion versus Li/S - Battery Requirement Spider Diagram
- Our Projections for 2025 – EVs
- Our Projections for 2025 – PHEVs
- Our Projections for 2025 – Strong HEVs
- Our Projections for 2025 – 48V Mild HEVs

#### 3. Battery Market by xEV Category

- Automotive Li-Ion Battery Business – 2015 Base Case
- Automotive Li-Ion Battery Business – 2015 Aggressive Case

#### 4. Materials Demand and Supply

- 2025 xEV Battery Material Demand
- Key Base Metal Demand for xEV Batteries
- 2025 Conclusion

### V. Directions of Individual Battery Makers

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

## 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