



TOTAL BATTERY CONSULTING REPORTS

Li Ion Batteries & Beyond

CRITICAL INSIGHTS INTO FUTURE CELL CHEMISTRY AND MATERIALS

Prof. Martin Winter

The xEV Industry Insider Report

ASSESSING THE FUTURE OF HYBRID AND ELECTRIC VEHICLES

Dr. Menahem Anderman

Battery Packs of Modern xEVs

A COMPREHENSIVE ENGINEERING ASSESSMENT

Kevin Konecky and Dr. Menahem Anderman

The Tesla Battery Report

TESLA MOTORS: BATTERY TECHNOLOGY, ANALYSIS OF THE GIGAFACTORY AND MODEL 3, AND THE AUTOMAKERS' PERSPECTIVES

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A SYSTEMATIC ACCOUNT OF WHY BATTERY SAFETY INCIDENTS OCCUR AND HOW TO AVOID THEM

Dr. Daniel Doughty

Li Ion Batteries & Beyond

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Author: Prof. Martin Winter

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This unique report evaluates advanced battery R&D work across the globe and highlights the most promising materials and cell technologies that will enable advances in battery technology and, with it, market expansion.

BENEFITS

Automakers, utility / industrial system integrators:

Consult the report’s critical review of future cell chemistry and material R&D to advance your planning and roadmaps.

Battery producers:

Use this all-inclusive assessment of the challenges associated with new cell chemistries and materials to better calibrate your development work.

Material developers / producers:

Benefit from this unbiased expert assessment of what is in the pipeline to sharpen your development strategy and funnel your R&D investment into the most promising technologies.

Corporate and financial investors:

Gain insights into the future of battery cell materials and chemistry to guide your investment decisions.

A critical assessment of what is in the research labs, what is likely to make it to the market, and why.

“Prof. Winter handles this complex topic with professionalism and authority.”

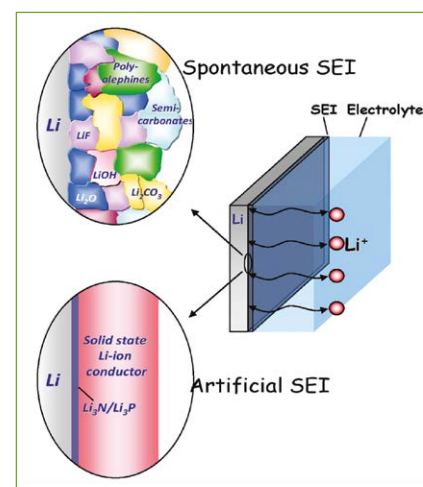
— Jeff Oren, *Primet Precision Materials*

“Prof. Winter’s presentation is impressive, structured, high content! Fascinating how much he covers in short time! A good presentation to explain science to engineers!”

— Roland Matthe, *General Motors*

“This was the 4th time listening to Prof. Winter’s presentations, and I am looking forward to the 5th time. Very good!”

— Kai Vuorilehto, *Skeleton Technologies*



The xEV Industry Insider Report

ASSESSING THE FUTURE OF HYBRID & ELECTRIC VEHICLES

Author: Dr. Menahem Anderman

A comprehensive analysis of the plans of major automakers and regional market conditions worldwide set against the cost/benefit ratios of emerging vehicles and battery technologies.

BENEFITS

Automakers:

Benefit from the report's balanced analysis of the future cost, performance, and durability of advanced automotive batteries.

Battery producers:

Gain insights into the direction of both the advanced automotive market and individual carmakers.

Material producers:

Learn about the prospects of battery materials in the xEV market.

Energy providers:

Stay abreast of the technology and trends behind vehicle electrification.

Corporate and financial investors:

Use this comprehensive assessment of the technology and market challenges to better guide your investment decisions.

REPORT OUTLINE

I. xEV Market Trends

1. Overview
2. Vehicle Markets by Region
3. Vehicle Market Forecast
4. Directions of Individual Automakers

II. Lithium-Ion Battery Technology for xEVs

1. Key Design Parameters
2. HEV Batteries
3. EV & PHEV Batteries

III. xEV Battery Market Forecast to 2020

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IV. Technology and Market Development to 2025

V. Directions of Individual Battery Makers

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KEY TOPICS

- EV and PHEV market expansion
- Recent developments in China
- Vehicle-market projections to 2025
- Battery-market projections to 2025
- Cost of xEV batteries
- 48V mild-hybrid challenges, opportunities, and energy-storage selection
- Tesla's success to date and its impact on the EV industry
- Status and future of Lead-Acid and Nickel-Metal Hydride batteries and ultracapacitors
- Performance, durability, and safety factors for automotive Lithium-Ion batteries

COMPANIES VISITED

Automakers/Automotive Systems:

- Audi
- AVL
- BMW
- Chrysler
- Continental AG
- Daimler
- Denso
- Ford
- Fuji Heavy Industries (Subaru)
- General Motors
- Honda
- Hyundai
- Mitsubishi Motors
- Nissan
- Opel AG
- Porsche
- PSA Peugeot Citroën
- Renault
- Robert Bosch
- Toyota
- Valeo

- Volkswagen
- ZF Sachs

Battery Producers:

- A123 Systems
- AESC
- Deutsche Accumotive
- GS Yuasa
- Hitachi
- Johnson Controls
- LG Chem
- Li Energy Japan
- Primearth EV Energy
- Panasonic-Sanyo
- Robert Bosch
- Samsung
- Toshiba

Other Participants:

- California Air Resources Board
- Hitachi Chemical
- Mitsubishi Chemical
- NEC Devices
- Umicore

"The xEV Report is relevant, it is not wading through pages and pages of information... it is exactly what we are looking for."

— Ted Miller, Ford

"There is certain data that you just cannot get elsewhere and we rely on the Report's analysis - especially cost information; so it is very valuable to us. It is worth the money - absolutely."

— William J. Wallace, General Motors

Battery Packs of Modern xEVs

A COMPREHENSIVE ENGINEERING ASSESSMENT

Authors: Kevin Konecky and Dr. Menahem Anderman

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1. xEV Battery System Key Design Attributes

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- ESS Design
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- ESS Battery Life
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- ESS Safety
- ESS Product Development Plan

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- EVs discussed in this section
- Battery packs for EVs – Analysis
- Vehicle-specific review for production EVs

3. Battery Packs for PHEVs

- PHEVs discussed in this section
- Battery packs for PHEVs – Analysis
- Vehicle-specific review for production PHEVs

4. Battery Packs for HEVs

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- Battery packs for HEVs – Analysis
- Vehicle-specific review for production HEVs

5. Charging Systems of EV/PHEVs

- Charging systems overview
- Charging standards
- Application usage of charging
- Vehicle trends for production EVs

An analysis of the battery-pack technology—cells, modules, and subsystems—used in 135 of the most recent xEVs.

A reference book for professionals in this industry.

Pack technology of the following OEMs:

- BMW
- BYD
- Daimler
- FCA
- Fisker
- Ford
- GM
- Honda
- Hyundai
- Mazda
- Mitsubishi
- Nissan
- Renault
- Subaru
- Tesla
- Toyota
- Volkswagen
- Volvo

| ESS Parameter | 2014 | 2015-16 |
|--------------------------|-------------|-------------|
| Pack Integrator | A123 | GM/LG |
| Cell Chemistry | Gr/LFP | Gr/LMO-NMC |
| Cell configuration | Pouch | Pouch |
| Configuration | 112s3p | 96s2p |
| Voltage (Vnominal) | 363 | 355 |
| Peak Power (kW) | 120 | 120 |
| Energy (kWhr) | 21.3 | 19 |
| P/E Ratio (kW/kWhr) | 5.6 | 6.3 |
| Mass (kg) | 254 | 215 |
| Specific Energy (Whr/kg) | 83.9 | 88.4 |
| BMS Type | Distributed | Distributed |
| Thermal System | Liquid | Liquid |
| Enclosure Material | Composite | Composite |

BENEFITS

Automakers:

Consult this review of the battery-pack technologies used in current xEVs to guide your future work.

Battery producers:

Gain insights into the trends of automotive battery-pack technology.

Component and subsystem producers:

Learn about automotive energy-storage system and subsystem design trends and individual cell and pack producers.

Corporate and financial investors:

Use this all-inclusive assessment of battery-pack technology to sharpen your investment decisions.



The Tesla Battery Report

TESLA MOTORS: BATTERY TECHNOLOGY, ANALYSIS OF THE GIGAFACTORY AND MODEL 3, & THE AUTOMAKERS' PERSPECTIVES

Author: Dr. Menahem Anderman



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- IX. Conclusion: Likely Scenarios for Tesla's Future
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 - Key characteristics of Tesla Vehicles and Battery
 - EV Battery Technology Background
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 - Module and Pack Design

BENEFITS

Automakers:

Profit from an independent assessment of the world's first new successful car company in decades and its battery technology.

Battery producers:

Learn from an independent expert's analysis of the company that overnight became the largest user of Li-Ion batteries in the world. Understand its battery technology, and anticipate the OEMs' response to Tesla's success.

Materials producers:

Explore Tesla's potential impact on the xEV battery supply chain and learn from the report's projections of the direction and growth rate of the market.

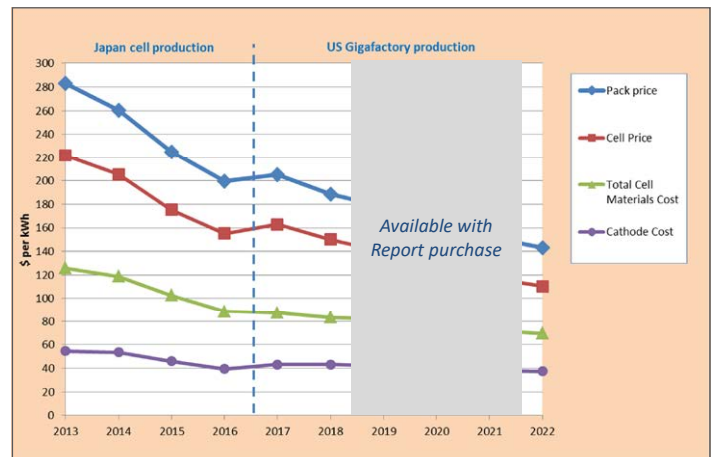
Energy providers:

Stay abreast of the emerging changes and trends in the EV market.

Corporate and financial investors:

Guide your investment decisions using the report's analysis of the realignment of the EV market in light of Tesla's success and impact on the battery industry.

Cost Summary (per kWh) for Tesla Battery*



*A detailed analysis is included in Section V.

“Dr. Anderman has very good and deep knowledge of the market.”
— Matthias Frey, Panasonic Industrial Group

Li Ion Battery Safety & Abuse Tolerance

A SYSTEMATIC ACCOUNT OF WHY BATTERY SAFETY INCIDENTS OCCUR AND HOW TO AVOID THEM

Author: Dr. Daniel Doughty

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- Cell Failures
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- Li-Ion Battery Safety & Abuse Characterization Tests
- Propagation of Thermal Runaway of Single Cell
- Abuse Tolerance Simulation
- Effect of Cell and Pack Design on Abuse Response

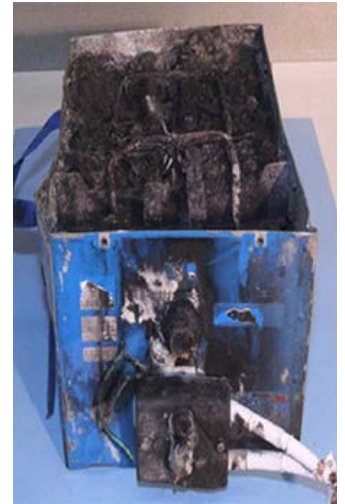
3. Safety Validation: Abuse Testing Methods & Procedures

- General
- Shipping Procedures
- Pass/Fail vs. Safety Characterization Tests
- Test Procedure Comparisons
- Functional Safety
- What's Missing

Summary and Conclusions

Appendix: Organizations that Publish Safety Test Standards

Safety concerns arise when batteries are abused, used outside the design's operational space, poorly designed, or beyond useful life. Heat generation and gas generation are the most common responses of batteries to abusive conditions--the most serious consequences occur when the stored energy is rapidly released in an unintended manner, triggering thermal runaway. This report presents the fundamentals of battery safety and abuse tolerance. It discusses materials, cells, and battery system design, manufacturing, applications, and validation, as well as the lessons learned from recent failures.



This report presents the fundamentals of battery safety and abuse tolerance. It discusses materials, cells, and battery system design, manufacturing, applications, and validation, as well as the lessons learned from recent failures.

BENEFITS

Automakers, utility / industrial system integrators:

Consult the report's critical review of cell, battery, and system safety to calibrate your own work in the field.

Battery producers:

Use this all-inclusive assessment of cell, battery, and system safety and the challenges associated with abuse tolerance and safety validation. Enhance your understanding of this crucial aspect of the technology and its role in your development work.

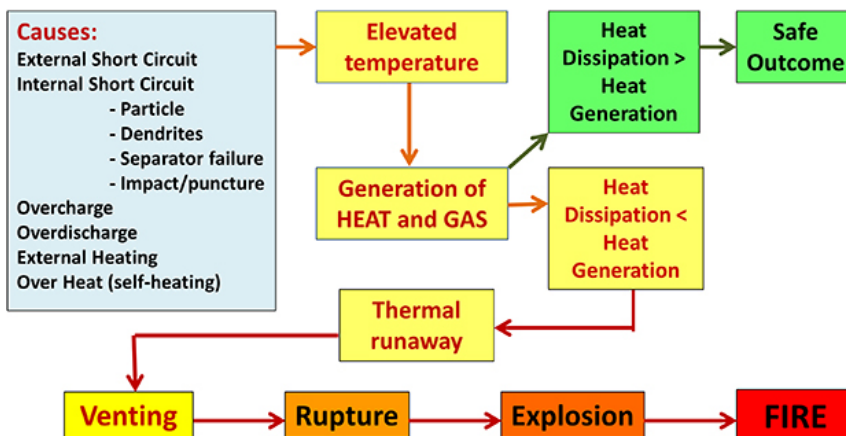
Material developers / producers:

Benefit from this unbiased expert assessment of materials, cell, and battery safety to sharpen your development strategy and funnel your R&D investment into the most promising technologies.

Corporate and financial investors:

Gain insights into the single largest risk associated with advances in battery technology and the financial exposure related to any investment in the field, to hone your investment choices.

Anatomy of Cell Failure



THE AUTHORS



Dr. Menahem Anderman,

President, Total Battery Consulting, Inc.
As the world's leading independent expert on advanced automotive batteries, Dr. Anderman provides technological assessments to companies worldwide. His client list includes most major automakers, leading international battery developers and suppliers, financial institutions, and government agencies. His access to automakers and battery companies gives Dr. Anderman insight into the latest trends in the advanced-vehicle market as reflected in his 2002 and 2007 Advanced Automotive Battery Industry Reports, 2005 Ultracapacitor Opportunity Report, 2010 / 2011 EV-PHEV Opportunity Reports, and his current reports, the xEV Industry Insider Report and The Tesla Battery Report.



Kevin R. Konecky

Mr. Konecky has 15 years of experience as engineering manager for Energy Storage Systems, predominantly for xEVs. He is skilled in component and subsystems design, integration, and testing. Mr. Konecky has worked on HEV packs as senior engineer or engineering manager for GM Allison, GM Tahoe, Cobasys - GM Saturn Vue, on EV packs for EnerDel - Volvo; and on PHEV packs for Fisker. As a consultant he has helped automakers and battery developers active in the U.S. and Chinese markets develop and validate xEV packs ranging from low-voltage HEVs to large EV battery systems.



Dr. Daniel Doughty,

President, Battery Safety Consulting, Inc.
Dr. Doughty founded his consulting firm in 2008 to provide independent expert consulting services for a wide range of battery safety issues, including failure analysis, test method development, interpretation of test results, expert witness and forensic consulting. In this capacity, he works with battery developers and integrators to secure and validate battery system safety under all foreseeable abuse conditions; he also assists standard and test organizations in establishing battery safety test standards.



Prof. Martin Winter,

Prof. Winter is the Founding Scientific Director of the MEET Battery Research Center as well as the Founding Director of the Helmholtz Institute "Ionics in Energy Storage", WWU Muenster, Germany. He oversees one of the largest battery R&D groups in the world with ca. 150 technical staff. Prof. Winter provides consulting to the automotive battery and materials industries and is the chairman of the advisory board of the Batterieforum as well as the spokesperson of the program Batterie2020 for the BMBF (Germany's Ministry of Education and Research). Prof. Winter was awarded the Research and Technology Awards of the Electrochemical Society (ECS) and the International Battery Materials Association (IBA) and the Carl Wagner Memorial Award of the ECS.

ORDERING INFORMATION

| | | |
|---|--|---------|
| Li Ion Batteries & Beyond (published February 2017) | Full report | \$4,600 |
| | Introduction + any two chapters | \$3,200 |
| | Introduction + one chapter | \$2,200 |
| xEV Industry Insider (July 2017 edition) | | \$3,800 |
| Battery Packs for Modern xEVs (June 2017 edition) | | \$2,800 |
| Tesla Battery Report (July 2017 edition) | | \$2,800 |
| Li Ion Battery Safety & Abuse Tolerance (published August 2016) | | \$2,800 |
| Corporate license for each report | | \$1,800 |
| Additional copies (only available with report purchase) | | \$150 |
| Two-hour follow-up consultation | | \$800 |
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- Acme Electric Corporation
- Altair Nanotechnologies
- Automotive Energy Supply Corporation

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- Battery Design Company
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- California Air Resources Board

- Copper Development Association
- CRA International
- CRI Advantage
- E-Motion Mobility
- Electric Power Research Institute
- EnBW Energie Baden-Wuerttemberg AG
- Exponent
- Field Support Services
- Fraunhofer Institute for Systems and Innovation Research
- Hon Hai Precision Ind. Co., Ltd.
- ICCT
- Idaho National Engineering and Environmental Laboratory
- IFP Energies Nouvelles
- Illinois Tool Works
- Instituto de Tecnologia Edson Mororo Moura
- ITRI
- National Research Council Canada
- New York University
- Nickel Institute
- Philips Research Laboratories
- Roland Berger Strategy Consultants GmbH
- SunEdison
- SVP Japan Co.
- Taiwan Industrial Technology Research Institute (ITRI)
- TRU Group
- TUM CREATE, Ltd.
- University of California, Davis
- VTT Technical Research
- US Department Of Energy

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- Applied Materials, Inc.
- Arkema
- Asahi Glass
- BASF Corporation
- Brueckner Maschinenbau GmbH & Co. KG
- Cabot Corporation
- Celgard
- Chemetall
- ConocoPhillips Company
- Corning
- Degussa
- Dow Chemical Company
- DuPont Company

- Engelhard Corporation
- Entegris
- Freudenberg & Co.
- Hanwha Chemical R&D Center
- Hollingsworth & Vose
- Honeywell
- Imerys Graphite & Carbon
- INCO Special Products
- Kimberly-Clark
- MeadWestvaco Corporation
- Merck KGaA
- Michelin
- Mitsubishi Chemical Corporation
- Mitsui Mining & Smelting Co., Ltd.
- Momentive
- Morgan Crucible
- Nanogram
- NGK-Locke, Inc.
- Nippon Shokubai Co.
- Occidental Material Group (OMG)
- Orion
- POSCO
- Primet Precision Materials
- Procter & Gamble
- Rogers Corporation
- Rohm and Haas Chemicals
- Sabic Innovative Plastics
- Schott AG
- SciMAT
- SGL Carbon
- Showa Denko
- Solvay
- SQM S.A.
- Süd Chemie
- Sumitomo Bakelite North America
- Sumitomo Corporation
- Ticona
- Toda
- Tonen Chemical
- Toray Battery Separator Film
- Umicore
- W.L. Gore & Associates
- Zeon Corporation

OIL COMPANIES

- BP America Production Company
- Chevron Texaco Corporation
- Exxon Mobil Chemical Co.
- Nippon Oil (U.S.A.)
- Nippon Shokubai Co.
- Shell Oil
- SK Corporation

Since 1996, Total Battery Consulting (TBC) has provided consulting and multi-client industry reports in the field of energy-storage development, application, and market, with particular emphasis on the advanced automotive battery market. In 2000, TBC's founder and President Dr. Menahem Anderman also founded the premier international event in the industry: the Advanced Automotive Battery Conference (AABC), which he has chaired ever since. The objective of Total Battery Consulting is to make information available to industry professionals around the world to help them focus their financial and human resources on the most technologically viable and economically affordable solutions for the needs of the automotive energy-storage industry. Supporting Dr. Anderman at TBC as consultants are Prof. Martin Winter of Muenster Electrochemical Energy Technology, Dr. Robert Spotnitz, President of Battery Design, LLC, and Mr. Kevin Konecky.



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