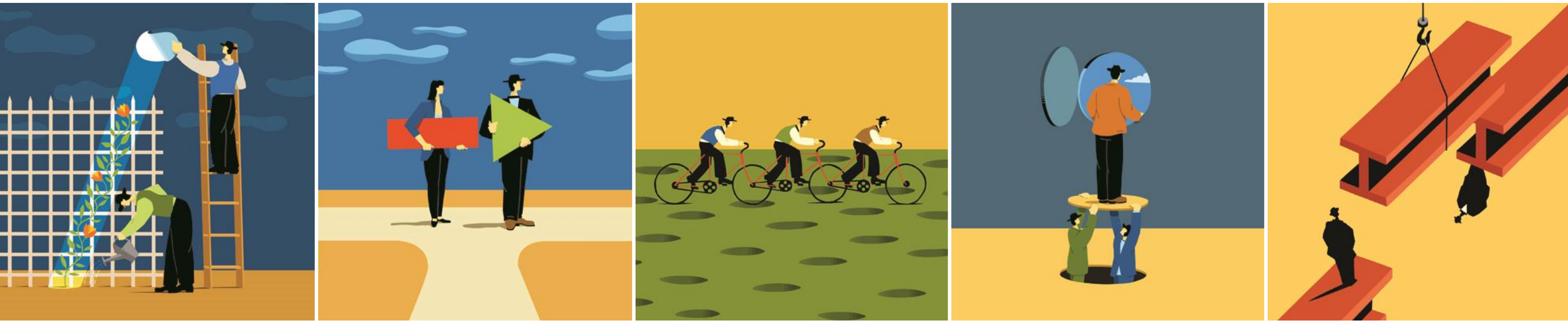
NAVIGANT RESEARCH



IEEFA ENERGY FINANCE 2015

MARCH 17, 2015

SAM JAFFE
PRINCIPAL RESEARCH ANALYST

MARKET INTELLIGENCE • ANALYSIS • BENCHMARKING

Introduction

NAVIGANT RESEARCH PROVIDES IN-DEPTH ANALYSIS OF GLOBAL CLEAN TECHNOLOGY MARKETS.

The team's research methodology combines supply-side industry analysis, end-user primary research and demand assessment, and deep examination of technology trends to provide a comprehensive view of the Smart Energy ecosystem.

RESEARCH PROGRAMS:

Smart Energy

Smart Utilities

Smart Transportation

Smart Buildings

RESEARCH OFFERINGS:

Research Reports

Subscription Research Services

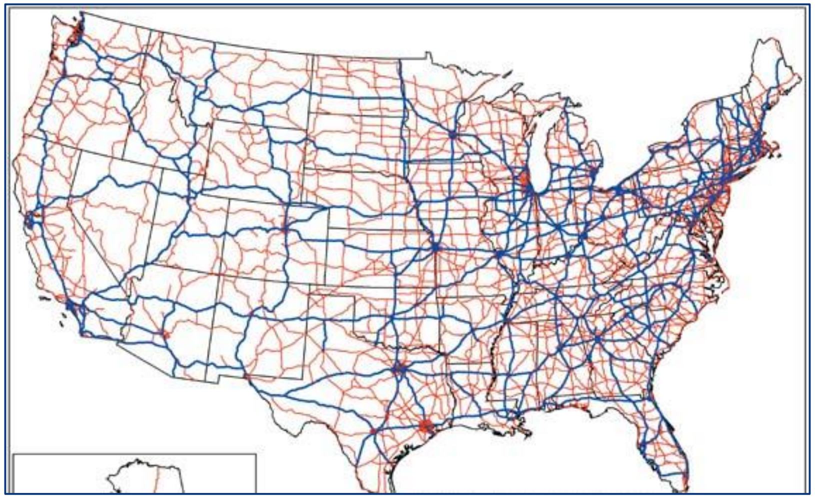
Custom Market Research

- Custom Market Analysis
- Market Sizing and Forecasting
- Primary Research
- Go-to-Market Services
- Strategic Advisory Sessions
- Commercial Due Diligence
- Technology Evaluation

NAVIGANT RESEARCH

SECTION 1
BATTERY HISTORY AND BACKGROUND

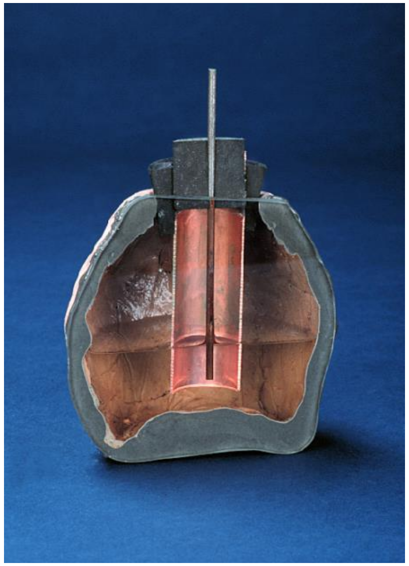
State of the Art Energy Storage 2010



NAVIGANT RESEARCH

The Baghdad Battery

(Source: Baghdad Museum)



(Source: Smith)

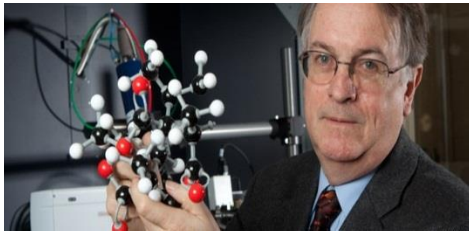
Commercial Battery History

- Daniell battery, developed in 1836, becomes the first commercial battery
- First lead-acid battery developed by Gaston Plante in 1859 for rail applications in France
- Rechargeable Li-ion battery developed by Dr. Stan Whittingham at Exxon in early 1980s
- Dr. John Goodenough of Texas developed the lithium cobalt chemistry and later the lithium iron phosphate chemistry
- Sony launched the first commercial Li-ion battery for consumer electronics in 1991
- Today, Li-ion powers most portable tools and devices, as well as most EVs and stationary storage systems

Plante Battery

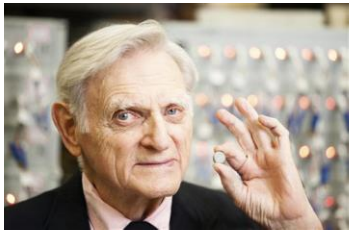
(Source: Wikimedia Commons)

Stanley Whittingham



(Source: SUNY Binghamton)

John Goodenough

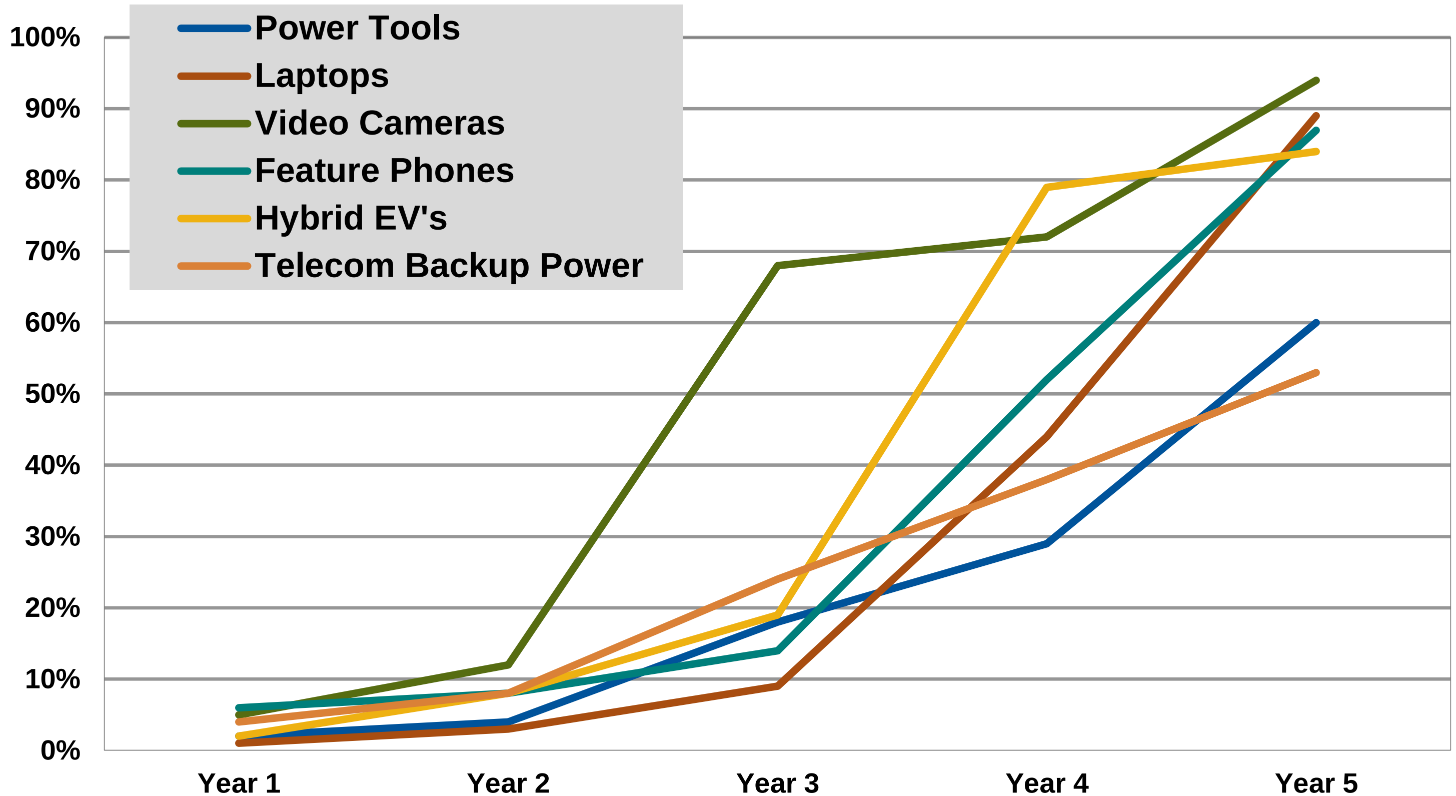


(Source: University of Texas)

NAVIGANT RESEARCH

Li-ion Inflection Point

Li-ion Market Share by Segment, World Markets: First 5 Years

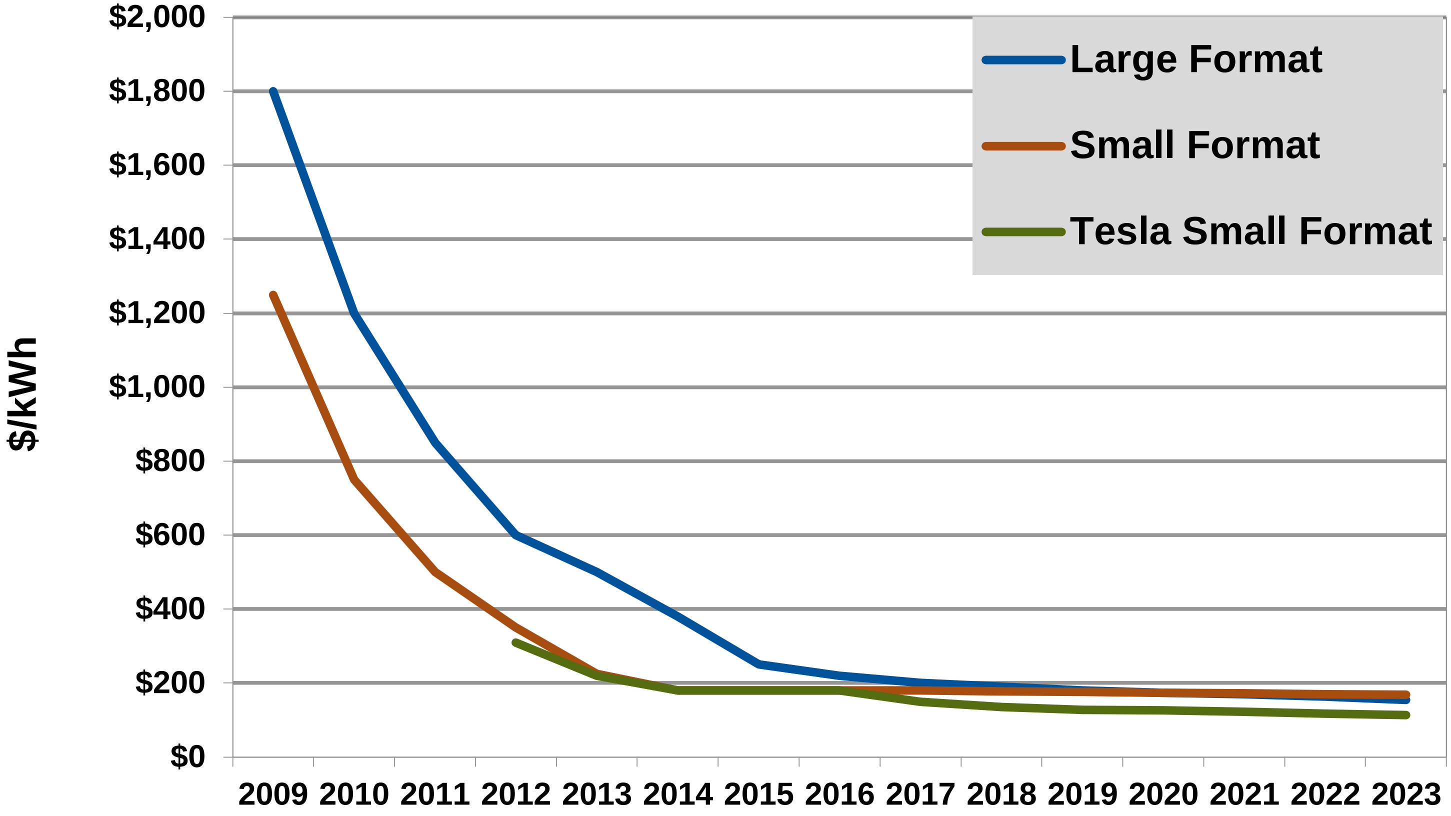


(Source: Navigant Research)

NAVIGANT RESEARCH

Lithium Ion Pricing Forecasts

Historical and Forecast Lowest-Point Pricing for Li-ion Batteries by Form Factor, 2009-2023



Source: Navigant Research

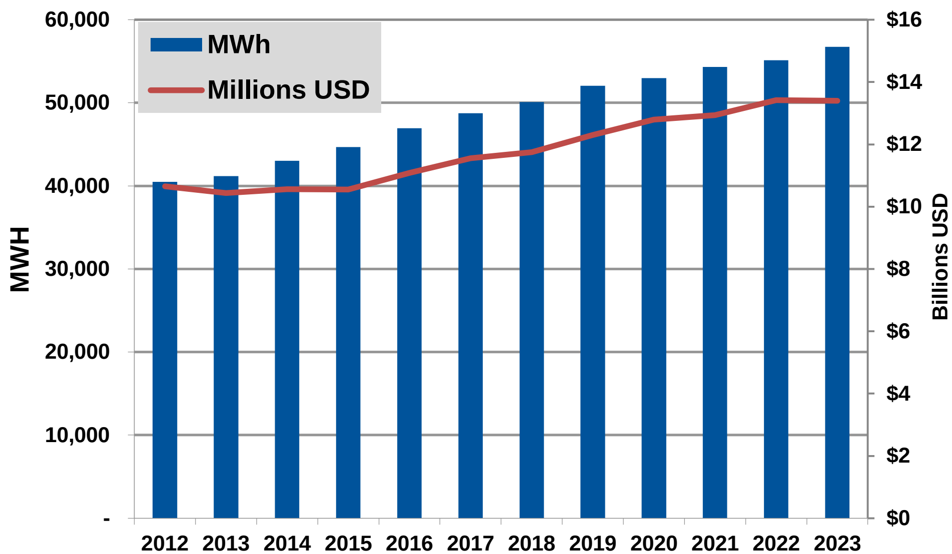
NAVIGANT RESEARCH

SECTION 2
BATTERY FORECASTS

NAVIGANT
RESEARCH

Advanced Battery Consumer Electronics Forecast

Advanced Batteries for Consumer Electronics Revenue by Region, World Markets: 2014-2023

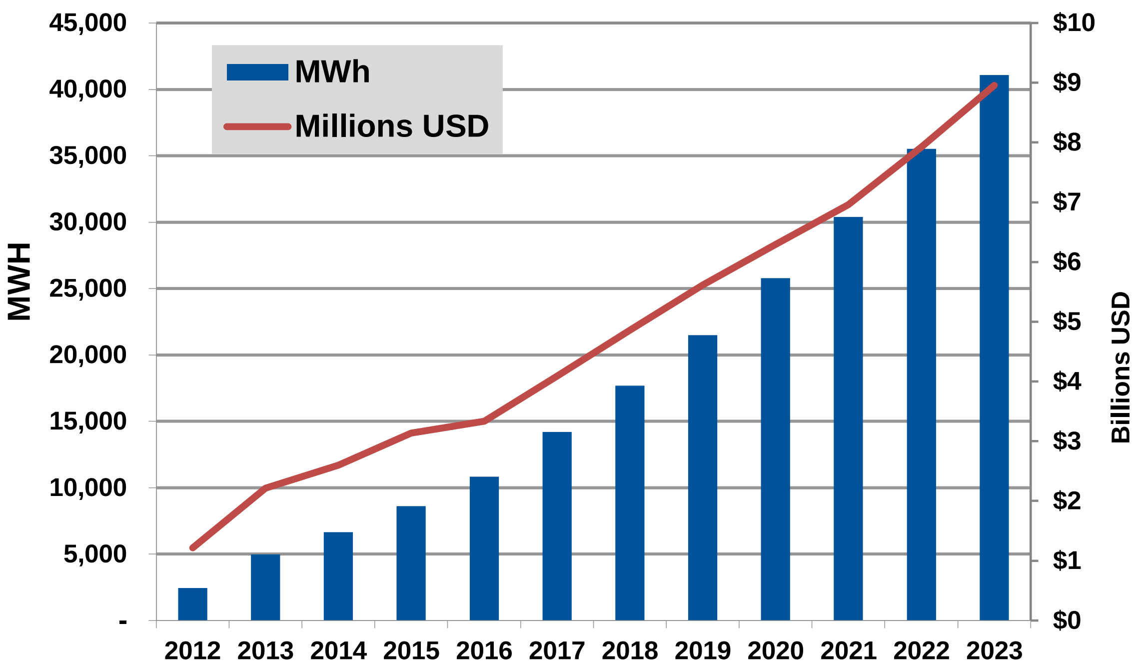


(Source: Navigant Research)

NAVIGANT RESEARCH

Advanced Battery EV Forecast

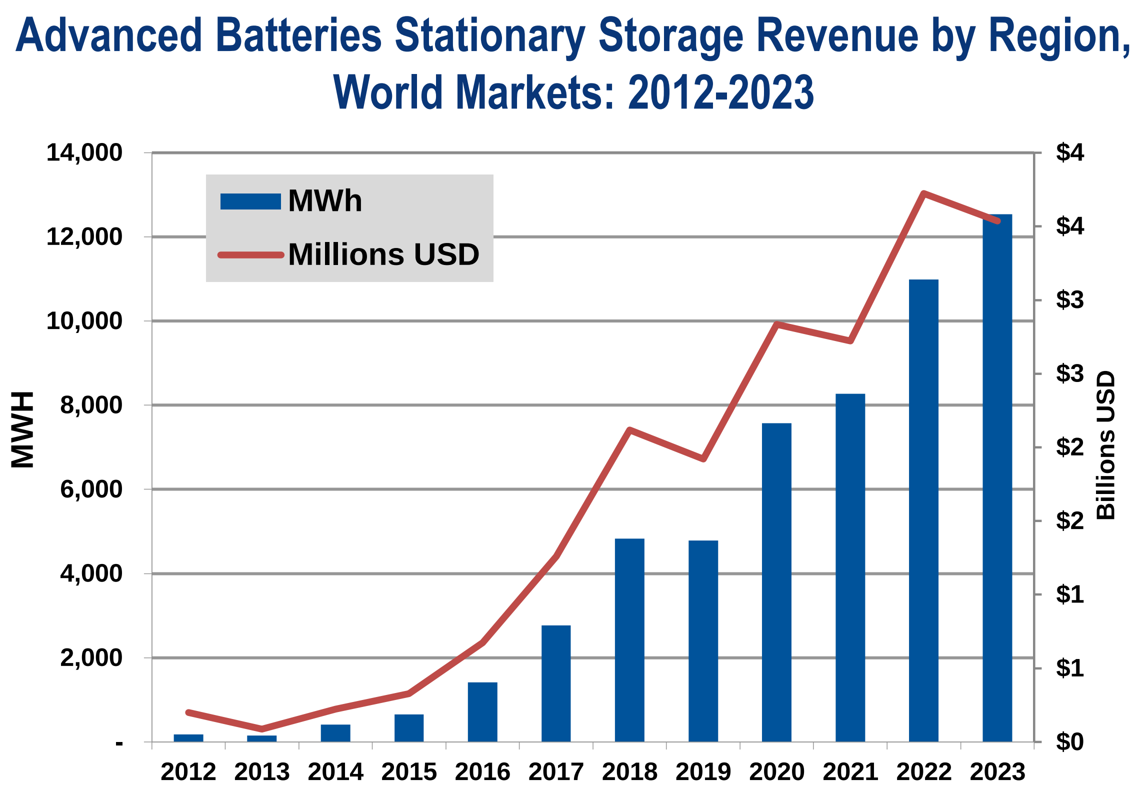
Advanced Batteries for XEV Revenue by Region, World Markets: 2012-2023



(Source: Navigant Research)

NAVIGANT RESEARCH

Advanced Battery Stationary Storage Forecast

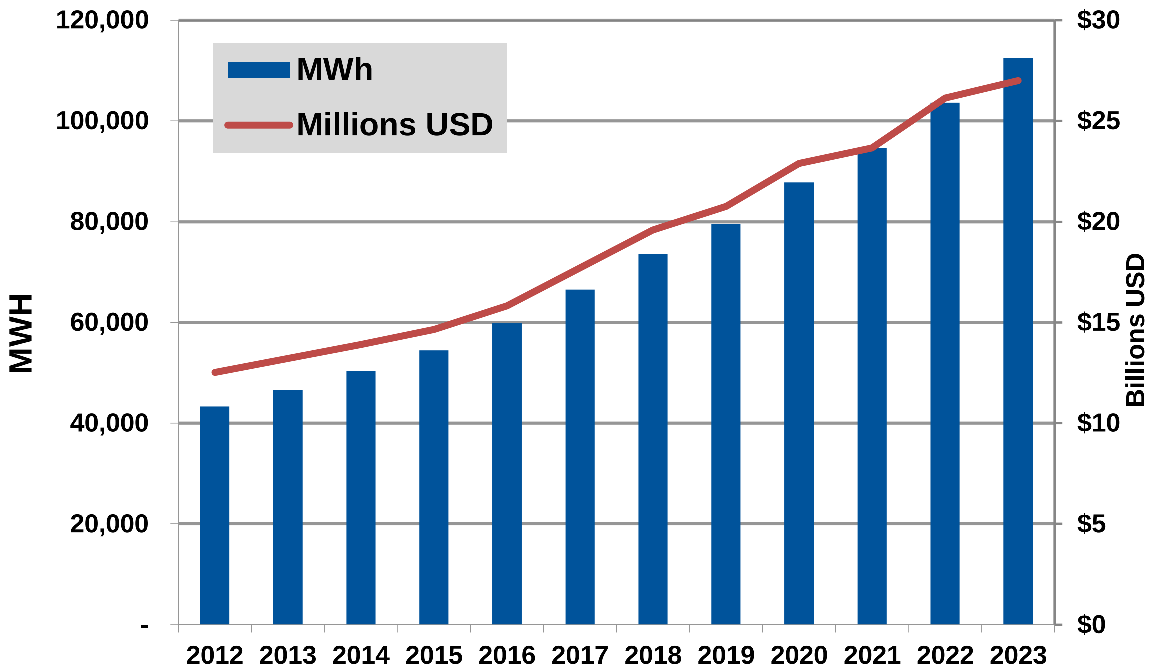


(Source: Navigant Research)

NAVIGANT RESEARCH

Global Revenue Forecast for All Advanced Batteries

Advanced Batteries Revenue All Applications, World Markets: 2014-2023



(Source: Navigant Research)

NAVIGANT RESEARCH

Key Policy and Regulatory Obstacles

- Defining Storage: Transmission, Distribution, Generation or Load?
- Creating Open Markets for Energy Storage Systems that monetize the unique qualities of the asset: PJM's approach to FERC Order 755
- How to Account for Application Stacking?
- Energy Storage System Ownership: Utility, Aggregator, Generator or Behind-the-Meter?
- Key Takeaway: Regulatory clarity is more important that subsidies.

NAVIGANT RESEARCH

Grid Storage Business Model Hypothetical Scenario: NG Peaker Plant Augmentation

- Natural Gas peaker plants provide most of the peaking requirements of the U.S. grid
  - Consist of single cycle combustion turbines (efficiency ~40%)
  - Able to ramp quickly, but cost of fuel is high, as well as high air pollution, high carbon intensiveness and poor energy security profile
  - Combined Cycle gas plants (efficiency ~55%) are too slow to ramp up and down in response to peak demands
  - Pair a CC-NG turbine plant with a large battery pack (1 GW and ~400 MWh of batteries) and you get a duty cycle that today's batteries can meet, a more efficient use of fossil fuels and a lower fuel cost; additionally you make the grid more flexible, allowing more renewables to penetrate without fears of destabilization

Lake Road CC Turbine Plant (Source: Alstom Power)

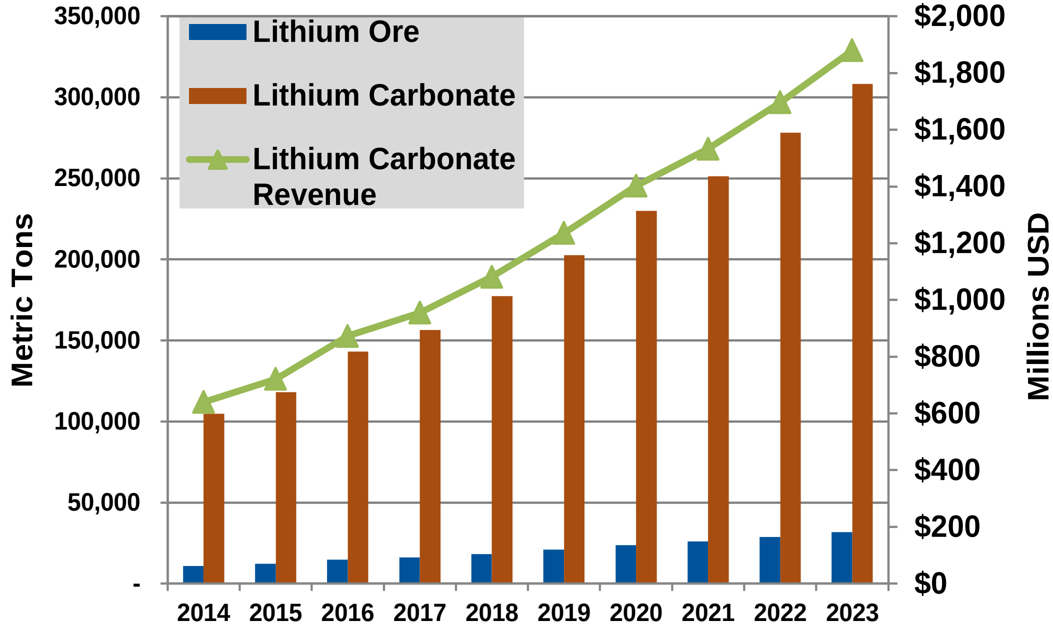
NAVIGANT RESEARCH

SECTION 4
BATTERY SUPPLY CHAIN AND MATERIALS AND THE GIGAFACTORY

NAVIGANT
RESEARCH

Battery Materials: Lithium

Forecast of Lithium Ore in Metric Tons and Lithium Carbonate in Metric Tons and Revenue, World Markets: 2014-2023



- Relatively small volume of Lithium ore goes into Lithium Carbonate
- Most new battery chemistries are still lithium based, so lithium batteries will be with us for at least the next two decades
- Navigant Research sees no significant threat of lithium shortages in the next ten years

Tesla Motors:
Pack Design-The Cell

» Chemistry

- Optimized for high power and long cycle life
- $LiNi_{0.76}Co_{0.14}Al_{0.10}O_2$ Cathode (NCA)
- Graphite Anode
- Voltage range of 3.6 to 4.05 V
- 90% capacity after 3,000 cycles
- Tesla NCA batteries use 25% of the cobalt that traditional LCO batteries use

» Cell design

- Central rod inside the jelly roll deforms at higher temperature, causing battery cell to collapse downwards in case of thermal runaway
- 18650 size
- More than 7,000 cells in a Model S pack

Patent Application Publication May 19, 2011 Sheet 5 of 5 US 2011/0117403 A1

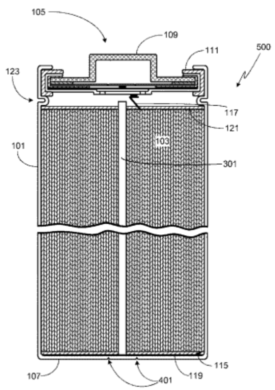


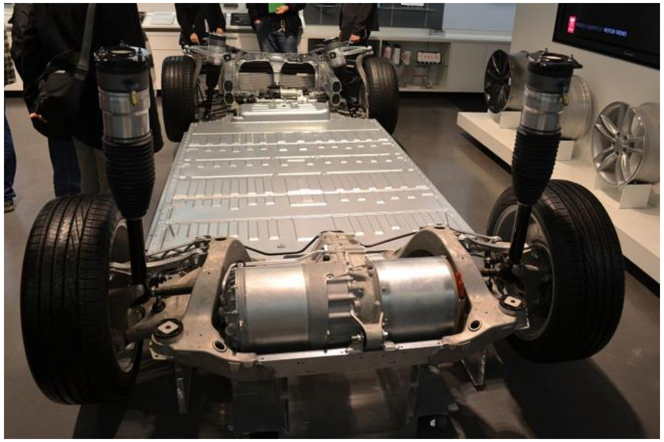
FIG. 5

Deformable center bar configuration
Source: Tesla Patent **20110117403**

NAVIGANT RESEARCH

Tesla Motors:
Pack Design-Costs

- Tesla has publicly stated that it pays somewhere between \$200 and \$300 per kWh for the entire battery pack Navigant Research estimates that it is spending ~\$180 per kWh for its Panasonic cells
- Costs for cells and packs will continue to decline in 2014 and 2015 (maybe 10-15%)
- With establishment of GigaFactory, Tesla will be producing cells at \$110-150per kWh



Model S Chassis
Source: Greentech Media

NAVIGANT RESEARCH

Tesla Motors:
GigaFactory-The Plan

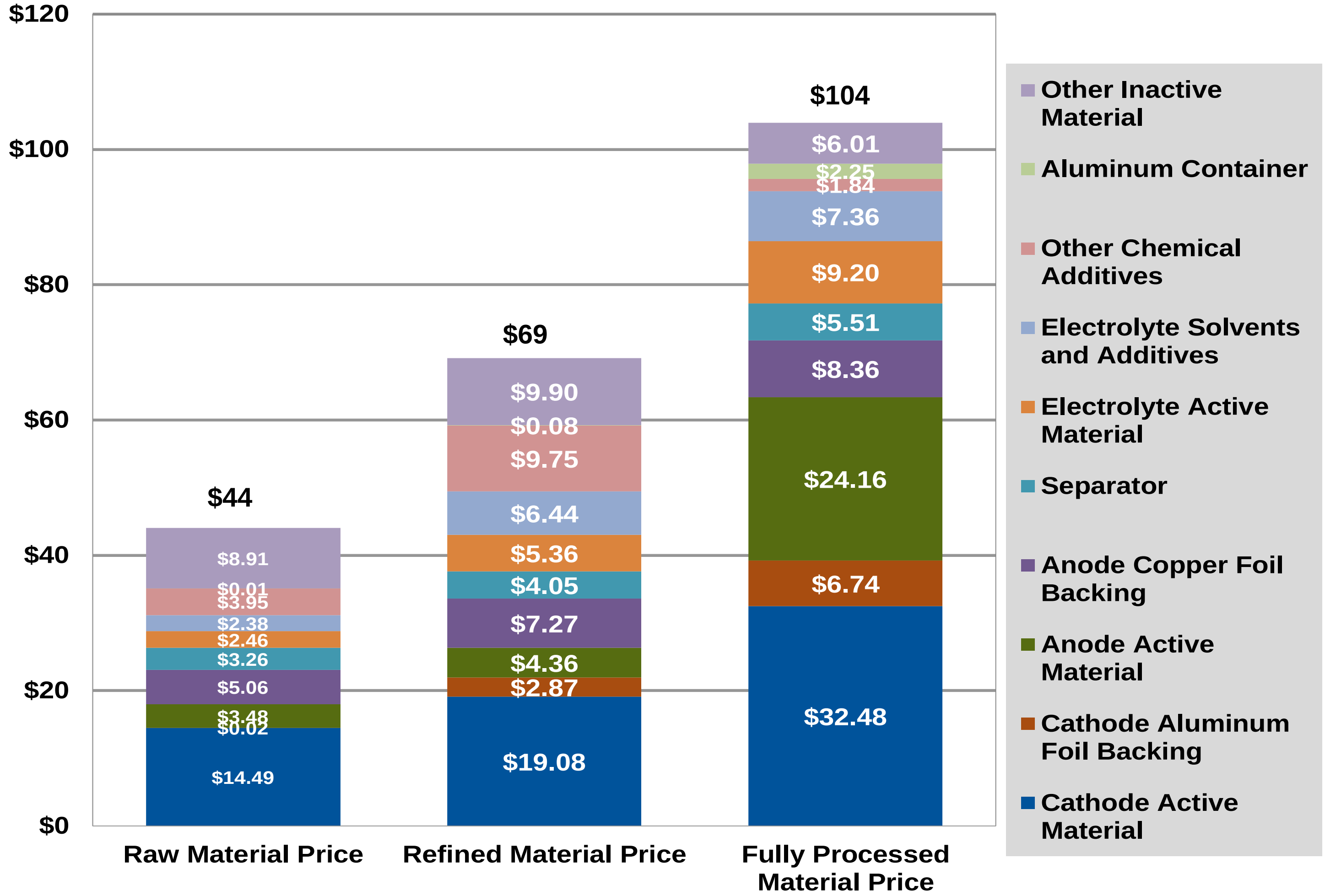
- 35 GWh cell capacity; 50 GWh pack capacity
- Integrated on-site renewables for “majority” of power needs
- “Soup-to-nuts” facility: raw materials go in one end, finished battery packs go out the other
- 6,500 employees
- Transportation of packs to NUMMI will be a minor cost, however rail is a requirement—if shipping is by truck, then shipping costs increase by 4x

GigaFactory rendering
Source: Tesla

NAVIGANT RESEARCH

Lithium Ion Materials Costs

Raw Material, Refined Material, and Fully Processed Material Costs for Li-Ion Batteries, 2014



NAVIGANT RESEARCH

Battery Transportation Logistics

- The Journey of a Molecule
  - A single Lithium molecule has 7 distinct trips before it is used by a consumer. All told, the molecule has travelled 29,875 miles to get to the user.
  - Those trips are:

    1: Molecule is mined in Chile and shipped to U.S. refinery to be turned into lithium carbonate (3,600 miles)

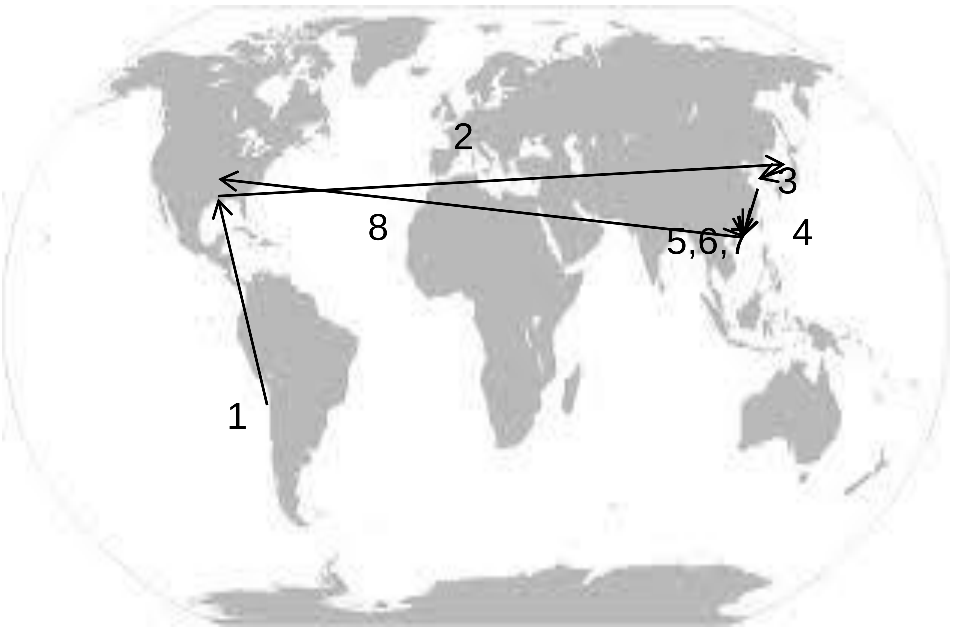
    2: Lithium carbonate is shipped from U.S. refinery to processing facility in Japan to be packaged and measured (17,360 miles)

    3: Lithium Carbonate is shipped to cathode powder facility in South Korea (715 miles)

    4: Cathode powder is shipped to China

    5,6,7: Powder is moved within China three more times to various distribution centers before finally getting to battery factory to be placed inside battery (1,300 miles)

    7: Finished battery is shipped from China back to U.S. to be placed in automobile (7,800 miles)



Source: Navigant Research

NAVIGANT RESEARCH

Contact Us

MAIN OFFICE

1320 Pearl Street, Suite 300
Boulder, CO 80302

Sam Jaffe: +1.303.493.5479
+1.303.502.4001 (m)
sam.jaffe@navigant.com

WORLDWIDE OFFICES

United States:	Boulder, Colorado Chicago, Illinois San Francisco, California Washington, D.C.
Europe:	Copenhagen, Denmark London, United Kingdom
Asia Pacific:	Seoul, South Korea

General information:	research-info@navigant.com
Sales inquiries:	research-sales@navigant.com
Media inquiries:	research-press@navigant.com

NAVIGANT RESEARCH