

Large-Format Rechargeable Lithium-Ion Batteries For Electric Energy Storage In Transport - Types, Applications, New Developments, Industry Structure And Global Markets

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Abstracts

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Large format, rechargeable lithium batteries are constructed from many lithium cells. These cells are typically connected together electrically to form what is commonly referred to as a “battery module.” Modules are then connected together electrically to form a “battery assembly.” Cells are used to construct modules which meet the definition of a “battery,” subject to testing requirements which include U.S., European and Japanese standards and one internationally accepted standard, the U.N. testing requirements.

With increasing size, battery manufacturers face dramatically increasing costs and testing complexities. The benefit of such extensive testing of assemblies is the guarantee that the Li-ion batteries will last – with unimpaired functionality, power and safety – for the required ten years or 160,000km to 240,000km.

Using Li-ion technology in vehicles poses particular challenges. The battery has to operate safely and reliably for the whole of the life cycle stipulated by the vehicle manufacturer, which is at least ten years. This is achieved by an elaborate battery management system which monitors the battery so that it is always within the optimum working range. The electronics compare the battery's overall condition, temperature and energy reserves against its age. Safety circuits prevent the energy storage unit from

becoming too hot. A cell supervision circuit (CSC) monitors the individual cells and ensures their optimum interaction. So that cells are not permanently subjected to uneven loads, the CSC balances the charge levels of all the cells in the battery.

Although, Pb-acid and nickel metal hydride (NiMH) batteries still control the transport energy storage batteries, lithium-ion batteries are currently emerging as an alternative source. These batteries not only come in a smaller and lighter package, but also provide twice the available power and twice the available energy density of the incumbent NiMH technologies. The efficiency that stems from the power and energy density solutions of lithium-ion chemistry is enabling a new generation of hybrid and electric vehicles that are more powerful and more energy efficient than ever before.

This iRAP report focuses on large format, high performance, rechargeable lithium batteries and their potential use in plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs), electric vehicles (EVs), light electric vehicles (LEVs) and heavy duty hybrid vehicles (HHEVs) which are the next great transportation advance that will move us into a cleaner, cheaper, and more oil-independent future.

STUDY GOAL AND OBJECTIVES

Sharp competition and legislation are pushing development of hybrid drive trains. Based on conventional internal combustion engine (ICE) vehicles, these drive trains offer a wide range of benefits, from reduced fuel consumption and emission to multifaceted performance improvements. The battery is the key component for all hybrid drive trains, as it dominates cost and performance issues. The selection of the right battery technology for the specific automotive application is an important task which impacts on costs of development and use. Safety, power, and high cycle life are a must for all hybrid applications.

The greatest pressure to reduce cost is in soft hybrids, where lead-acid batteries present the cheapest solution, with a considerable improvement in performance needed. From mild to full hybridization, an improvement in specific power makes higher costs more acceptable, provided that the battery's service life is equivalent to the vehicle's lifetime. Today, this is proven for the nickel-metal hydride system (NiMH system). Lithium-ion batteries, which make use of a multiple safety concept, with further development anticipated, provide even better prospects in terms of performance and costs. Also, their scalability permits application in battery electric vehicles – the basis for better performance and enhanced user acceptance.

The next generation of large format, rechargeable, lithium-ion batteries has improved safety characteristics in part through the use of alternative, nanosized materials, particularly phosphates. Traditional Li-ion technology uses active materials with particles that range in size from 5 microns to 20 microns.

This report identifies the trends and strategies driving large format, rechargeable lithium battery market segments, and focuses on detailed market share data and quantification in transport applications including:

- electric vehicles/plug-in hybrid electric vehicles (PHEVs);

- light duty (passenger vehicles);

- medium duty (trucks, etc.);

- heavy duty (heavy equipment).

Non-road electric vehicles include:

- fork lifts, material handling equipment, personnel carriers and cleaners;

- airport ground support equipment (GSE) – (electrification of ground support equipment at airports).

Electric idling initiatives (substituting electrification for petroleum-fueled idling operations) include:

- "cold ironing" - cruise ship and cargo terminals;

- locomotive electric idling;

- truck stop electrification.

This study provides market data about the size and growth of the battery application segments, new developments including a detailed patent analysis, company profiles and industry trends. The goal of this report is to provide a detailed and comprehensive multi-client study of the market in North America, Europe, Japan, China, India, Korea and the rest of the world (ROW) for large format rechargeable lithium batteries, and potential business opportunities in the future.

The objectives include thorough coverage of the underlying economic issues driving the large format, rechargeable lithium battery, as well as assessments of new advanced nano-enabled battery that are being developed. Another important objective is to provide realistic market data and forecasts for large format, lithium battery usage. The study provides the most thorough and up-to-date assessment that can be found anywhere on the subject. The study also provides extensive quantification of the many important facets of market developments in large format, rechargeable lithium batteries all over the world. This, in turn, contributes to the determination of strategic responses companies may adopt in order to compete in this dynamic market.

REASONS FOR DOING THE STUDY

Demand for battery solutions is being driven by a need to reduce dependence on oil, as well as growing concern about vehicle emissions. From 13 hybrid models in 2008, the market is expected to grow to nearly 75 hybrid models in 2014. In addition to the automobile market, applications for lithium-ion (Li-ion) battery technology include medical, military, aerospace, electric utility and other growing markets. Advanced lithium-ion battery technology is a basic need for every automaker in the world today, and it will grow steadily. Practically all major original equipment manufacturers (OEMs) are working on a Li-ion battery.

The transition period from the petro-car to the electric car will feature an interesting horse race between the Li-ion battery and an upgraded nickel metal hydride (NiMH) battery. Presently, hybrid electric vehicles (HEV) typically use batteries based on NiMH technology, which use simple control circuits but are heavier and operate at lower voltages. Li-ion batteries, widely used in portable consumer electronic equipment, offer a solid energy-to-weight ratio at more than twice that of NiMH batteries, with a very low self-discharge while not in use. However, their use in higher power applications has so far been limited because the charge/discharge cycle of Li-ion batteries must be carefully managed to protect the batteries from abuse conditions.

Further, the anticipated growth of plug-in hybrid electric vehicles (PHEVs) and rising

costs of traditional transportation fuels have accelerated the development of large format, rechargeable lithium batteries technology. Today, developers of advanced batteries are focusing on electric vehicles as a key target application, with variations based on the chemistry selected and other key factors such as the size of the system or the amount of energy it will store.

Worldwide, Li-ion research and development expenditures are about \$1 billion per year, which may drive the price of the technology lower, which will cause steady growth rate in the large format, rechargeable, lithium battery industry. OEMs of PHEVs require longer run times and slower drain rates, higher capacity at lower prices, and increasingly enhanced power capabilities. Technologically, it is a mature market. The most difficult hurdle for PHEVs is the battery. The goals for a PHEV battery are compact size, high energy, large storage capacity, and the ability to support both deep and shallow discharge cycles. With today's technology, a battery that is powerful and durable enough to power a PHEV's motor takes up more space than many vehicle makers or consumers are willing to sacrifice. Fortunately, with quickly evolving battery technologies, these issues are likely to diminish.

With all these developments, iRAP felt the need to conduct thorough technology, industry and market analyses of lithium-ion batteries.

CONTRIBUTIONS OF THE STUDY

Current battery technologies are limited, making plug-in hybrid or all-electric cars prohibitively costly and insufficient to meet consumer demands. Long-term, fundamental research in electrical energy storage will be needed to accelerate the pace of scientific discoveries and to see transformational advances that bridge the gaps in cost and performance, separating the current technologies and those required for future utility and transportation needs.

This report analyzes the worldwide markets for large format, rechargeable lithium batteries already using lithium manganese oxide, lithium iron phosphates, titanium oxide, silicon/graphite composites, and lithium polymer, related to transport electric energy storage applications such as plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs), electric vehicles (EVs), light electric vehicles (LEVs) and heavy duty hybrid electric vehicles (HHEVs).

The report provides the most thorough and up-to-date assessment that can be found anywhere on the subject. The study also provides extensive quantification of the many

important facets of market developments in the emerging markets of large format, rechargeable lithium batteries, for example, in high power density and high energy density electric energy source. This, in turn, contributes to the determination of what kind of strategic response suppliers may adopt in order to compete in this dynamic market.

SCOPE AND FORMAT

The market data contained in this report quantifies opportunities for large format, rechargeable lithium batteries. In addition to product types, it also covers the many issues concerning the merits and future prospects of the large format lithium battery business, including corporate strategies and the means for providing these highly advanced products and service offerings. It also covers, in detail, the economic and technological issues regarded by many as critical to the industry's current state of change.

The report provides separate comprehensive analyses for the U.S., Japan, western Europe, China, Korea, and the rest of the world. Annual forecasts are provided for each region for the period 2009 through 2014. Cost analysis of large-format lithium-ion batteries, analysis of global patent activity, and market competition and dynamics in the new technology are also targeted in the report. The report profiles 30 companies, including many key and niche players worldwide, as technology providers, raw material suppliers and large-format battery assemblers.

TO WHOM THE STUDY CATERS

The study would benefit existing OEMs supplying or intending to supply to manufacturers of hybrid vehicles, PHEVs, EVs, LEV, and HHEVs who are looking for vehicle batteries which require longer run times and slower drain rates, higher capacity at lower prices, and increasingly enhanced power capabilities. Large format, rechargeable, lithium batteries are specifically engineered as a power battery able to supply short burst of electrical energy, as opposed to an energy battery designed for longer, slower power drains found in an electric car. This makes them ideal for use in hybrid-electric cars as well as other applications, including lawn care and garden equipment.

This study provides a technical overview of the large format, rechargeable, lithium-ion batteries, especially recent technology developments and existing barriers. Therefore, audiences for this study include marketing executives, business unit managers and

other decision-makers in the market, as well as those in companies peripheral to this business.

The report also analyzes the strategies and prospects of leading firms active in this space. It will be of interest to:

firms in the battery and power spaces who want to understand the next wave of opportunities and how the new battery and fuel cell technology will impact them in the future;

advanced materials, components and sub-contract manufacturing companies who need to analyze the potential for selling their products and services into the large format, rechargeable, lithium-ion battery power segment;

investment bankers, venture capitalists and private equity investors who need a realistic appraisal of the revenue potential and timeframes associated with the advanced energy storage technologies based on nanostructured materials.

REPORT SUMMARY

Low-cost, long-life lithium batteries are seen as essential for accelerated development of alternative power vehicles, ranging from the now familiar gasoline-electric hybrids that double normal fuel economy to hydrogen fuel cell vehicles that use no petroleum.

Efficient energy storage systems for hybrid drives will acquire increasing significance in the future. It is precisely storage systems such as lithium-ion technology that will greatly affect the performance and costs of hybrid vehicles, plug-in hybrids and electric vehicles. Preferably, small and light systems with a simultaneously high capacity for charging and discharging are required. Besides increasing the performance, the development work centers on the service life of the battery systems in various drive cycles and temperature ranges.

Plug-in hybrid electric vehicles (PHEVs) and electric cars need more robust lithium batteries than conventional hybrids, because the batteries undergo a more severe duty cycle, charged to the brim and then nearly drained. Today's large-format, rechargeable lithium batteries have a modular embedded micro-controller battery management system (BMS), with thousands of lithium cells connected in-loop to take care of

proprietary safety, state-of-charge, state-of-health, balancing and diagnostics algorithms, which together serve to maximize the utility and reliability of systems solutions. They also have a variety of available communications interfaces (CAN, J1939, RS-232, etc.) to facilitate the seamless integration of the battery into the vehicle system.

Major findings of this report are:

The 2009 market was estimated to be about \$80 million. In 2009, we estimate the market to be flat or going down slightly, to \$77 million. In spite of the recession, iRAP estimates the market to reach \$332 million in 2014, for an average annual growth rate (AAGR) of 33.9%. Midway through the projection period, it is estimated that Li-ion batteries for HEVs, PHEVs and EVs will be in wider use, thereby providing a large growth rate.

Customized batteries for off-road vehicles and industrial vehicles such as electric fork lifts, golf carts and motorized wheel chairs, will have highest market share, reaching 51.9% of the market in 2009; by 2014, this share will decrease to 15%. In 2014, large-format lithium batteries for HEVs, PHEVs and EVs will have a 26.6% share of the global market, at \$88 million.

Contents

INTRODUCTION

Study Goal and Objectives
Reasons for Doing the Study
Contributions of the Study
Scope and Format
Methodology
Information Sources
Whom the Study Caters To
Author's Credentials

EXECUTIVE SUMMARY

Summary Table Market for Large-Format, Rechargeable Lithium Batteries By Type of Vehicle, Through 2014 (\$ Millions)
Summary Figure Market for Large-Format, Rechargeable Lithium Batteries By Type of Vehicles Used (\$ Million)

INDUSTRY OVERVIEW

Table 1 Popular Models of Hevs, Phevs and Evs Targeted for Lithium Battery Usage
Table 2 Types of Large-Format Lithium Battery for Transport (Electric Energy Storage) Chemistries and Their Capabilities
Table 3 Large-Format, Rechargeable Lithium-Ion Battery Cells-Related Parts Suppliers Manufacturers, System Integrators, Product Line Reference5

TECHNOLOGY OVERVIEW

Large-Format, Rechargeable Lithium-Ion Batteries

Cell Design

Cell Protection System

Thermal Management

Power Interface

Control Interface

Packaging

Battery Management Systems (Bms) in Large Rechargeable Lithium-Ion Batteries in Vehicles

Electrical Management

Thermal Management

Safety

&Nbsp; working principles of lithium-ion batteries

Figure 1 schematic of a lithium-ion cell

materials and systems for li-ion batteries

lithium nickel cobalt manganese (ncm or nmc)

Lithium Nickel Cobalt Aluminum

Lithium Manganese Oxide (Lms)

Lithium Iron Phosphate (Lfp)

Lithium Titanate Oxide Nanostructured Material As Anode

Lithium Polymer

Lithium Metal Polymer – LMP

Figure 2 Lithium Metal Polymer Cell Construction

Cathodes

Table 4 Cathode Electrode Material Energy Ratings

anodes

Separators

Electrolyte

Table 5 Electrolytes Used in Large-Format Lithium Batteries

Organic Solvents

Table 6 Organic Solvents Used in Large Format Lithium BATTERIES

Table 7 Type of Electrolytes Used According to Type of Lithium Cells

Cell Packaging

Safety Circuits

Module and Battery Pack Materials

Testing

Function of Rechargeable Lithium-Ion Batteries V/S Nickel Hydrid Batteries

Lithium-Ion Battery Safety

How Cell Types Differ

Figure 3 Schematic of a Cylindrical Lithium-Ion Cell

From Cells to Modules to Battery Packs

Figure 4 Schematic Illustration of a Cell, Module and Pack

Figure 5 Different Shapes of Cells Used in Lithium Batteries

APPLICATIONS

Heavy Duty Hybrid Electric Vehicles

Table 8 Multiple Types of Hybrid Vehicles

On-Road Electric Vehicles

Table 9 Comparison of Hev, Phev and Heavy Duty Hybrid Vehicle Technologies

Off-Road Vehicles and Industrial Vehicles

Light Electric Vehicles

Battery Requirements

Table 10 Typical Specifications of Large-Format Batteries for Bicycles / Ebikes / Scooters

Batteries for Other Applications – Hevs, Phevs and Evs

Hybrid Light Vehicles

Batteries for Hevs

Plug-In Hybrid Vehicles

Electric Vehicles/Zero Emission Vehicles (EV/ZEV)

Mini EV

Full EV

Batteries for Electric Vehicles and Zero Emission Vehicles

INDUSTRY STRUCTURE

Table 11 Large-Format and Small-Format Battery Usage

Leading Vehicle Manufacturers Working With Lithium Batteries

Large-Scale Investments

Joint Ventures and Tie-UPS

Table 12 Major Battery Manufacturers and Vehicle Oems Tie-UPS for Future Large-Format Lithium Batteries for Transport Applications

Price Analysis of Large-Format Lithium Batteries (Case Study: HEVS)

Figure 6 Cost Contributions of Hev Components and Cost Contribution of Battery Components in Large-Format Lithium Batteries

Price Analysis of Cylindrical Cells 18650 Used in Large-Format Lithium Ion Batteries (Case Study: PHEVS/EVS/FPBEVS/ZEVS)

Table 13 Example of Large-Format Lithium Battery Assemblies and Cell Constituents

Table 14 Price Analysis of Cell Type 18650 Lithium Manganese Oxide and Other Chemistries

R&D Funding

Table 15 Funding Announcements to Develop Advanced Lithium Batteries (Through May 14, 2009)

GLOBAL MARKET AND REGIONAL MARKET SHARES

Effect of Auto Industry Meltdown and Falling Oil Prices On the Market

Market According to Types of Vehicles

Table 16 Volume of Large-Format, Rechargeable Lithium Batteries Used in HEVS, PHEVS and Evs in 2009 and 2014

Information Sources and Basis of Market Estimation

Table 17 Market for Large-Format Rechargeable Lithium-Ion Batteries, 2009

Table 18 Market for Large-Format Rechargeable Lithium-Ion Batteries, 2014

Table 19 Market for Large-Format Rechargeable Lithium-Ion Batteries By Type of Vehicle (\$ Million)

Figure 7 Market Share of Large-Format Rechargeable Lithium-Ion Batteries By Type of Vehicle

Market for Large-Format Rechargeable Lithium-Ion Batteries By Cell Chemistry

Table 20 Market for Rechargeable Lithium-Ion Batteries for Transport By Material Chemistry, Through 2014 (\$ Millions)

Figure 8 Market for Rechargeable Lithium-Ion Batteries for Transport By Material Chemistry

Market for Large-Format, Rechargeable Lithium-Ion Batteries By Region

Table 21 Market for Rechargeable Lithium-Ion Batteries for Transport By Region, Through 2014 (\$ Millions)

Figure 9 Market for Rechargeable Lithium-Ion Batteries for Transport By Region (\$ Millions)

PATENTS AND PATENT ANALYSIS

List of Patents

&Nbsp; Large-Format Lithium Batteries – U.S. Patent activity

Battery Management System

Nanoparticle-Based Powder Coatings and Corresponding Structures

Lithium Secondary Cell With High Charge and Discharge Rate

Structures, Systems and Methods for Joining Articles and Materials and Uses

Therefore

Battery Controller and Method for Controlling a Battery

Post-Deposition Encapsulation of Nanostructures: Composition, Devices and Systems Incorporating the Same

Method and Apparatus for Dissipation of Heat Generated By a Secondary Electrochemical Cell

Methods and Apparatus for Deposition of Thin Films

Methods of Making, Positioning and Orienting Nanostructures, Nanostructure Arrays and Nanostructure Devices

Array-Based Architecture for Molecular Electronics

Nanocomposites
Synthesis of Metal Phosphates
Electrodes Comprising Mixed Active Particles
Particulate Electrode Including Electrolyte for a Rechargeable Lithium Battery
Circuits, Apparatus, Electrochemical Device Charging Methods, and Lithium-Mixed
Metal Electrode Cell Charging Methods
Secondary Battery Electrode Active Materials and Methods for Making the Same
Oligo Phosphate-Based Electrode Active Materials and Methods of Making Same
Lithium-Based Active Materials and Preparation Thereof
Process for Making Nanosized Stabilized Zirconia
Lithium Secondary Battery and Positive Electrode for the Same
Method for Producing Mixed Oxides and Metal Oxide Compounds
Methods of Making, Positioning and Orienting Nanostructures, Nanostructure Arrays
and Nanostructure Devices
Methods of Making Lithium Metal Cathode Active Materials
Method of Manufacturing Nanosized Lithium-Cobalt Oxides By Flame Spraying
Pyrolysis
Positive Electrode Active Material for Secondary Battery and Non-Aqueous
Electrolyte Secondary Battery Comprising the Same
Lithium-Containing Phosphate Active Materials
Process for Making Lithium Titanate
Lithium-Based Active Materials and Preparation Thereof
Process for Making Nanosized and Sub-Micron-Sized Lithium-Transition Metal Oxide
Stochastic Assembly of Sublithographic Nanoscale Interfaces
Methods of Positioning And/Or Orienting Nanostructures
Stabilized Electrochemical Cell Active Material
Salts of Alkali Metals of N, N' Distributed Amides of Alkane Sulfinic Acid and Non-
Aqueous Electrolytes On Their Basis
Lithium Metal Fluorophosphate Materials and Preparation Thereof
Lithium Secondary Battery
Particulate Electrode Including Phosphates and Related Electrode Active Materials
Alkali Transition Metal Phosphates and Electrode Active Materials
Power Supply Apparatus and Power Supply Operational Methods
Electrical Power Source Apparatus, Circuits, Electrochemical Device Charging
Methods
Alkali Metal Hydrogen Phosphates As Precursor for Phosphate-Containing
Electrochemical Active Materials
Non-Aqueous Electrolyte Secondary Cell
Negative Electrode for Rechargeable Battery

Alkali/Transition Metal Halo- and Hydroxyl-Phosphates and Related Electrode Active Materials

Electrical Energy Apparatus Uses, Electrical Energy Conditioning Circuits, and Electrical Supply Methods

Composite Active Material and Process for the Production, Electrode and Process for the Production, and Non-Aqueous Electrolyte Battery

Composite Active Material and Non-Aqueous Electrolyte Battery

Methods of Making Transition Metal Compounds Useful As Cathode Active Materials
Circuits, Apparatus, Electrochemical Device Charging Methods, and Lithium-Mixed Electrode Cell Charging Methods

Lithium-Based Active Materials and Preparation Thereof

Lithium-Containing Phosphates, Method of Preparation, and Uses Thereof

Lithium Cell Based On Lithiated Transition Metal Titanates

Lithium-Containing Phosphates and Method of Preparation

Positive Active Material for Secondary Battery and Non-Aqueous Secondary Battery

Secondary Lithium Battery Construction for Improved Heat Transfer

Lithium-Containing Materials

Synthesis of Lithiated Transition Metal Titanates for Lithium Cells

Preparation of Lithium-Containing Materials

Preparation of Lithium-Containing Materials

Lithium Manganese Oxide and Lithium Secondary Battery

Method for Producing Catalyst Structures

Patent Analysis

TABLE 22 Number of U.S. Patents Granted to Companies for Large-Format, Automotive Grade, Rechargeable Lithium Batteries From 2004 to October 2008

FIGURE 10 Top Companies in Number of U.S. Patents Granted for Large Format Lithium Batteries for Transport From 2004 to 2008

International Overview of U.S. Patent Activity in Lithium Batteries

Table 23 Number of U.S. Patents Granted By Country/Region for Large-Format, Automotive Lithium Batteries From 2004 to Dec 2008

Important Selected World Patents

WO/2007/116971 - Lithium Transition Metal-Based Compound Powder for Positive Electrode Material in Lithium Rechargeable Battery

WO/2002/011217 – Particulate Electrolyte for a Rechargeable Lithium Battery

WO/2007/132993- Bms Having Waterproof Function

WO/2006/082425) – a Battery Management System for Use in One Or More Cells

WO/2008/068446 –Battery Management System

WO/2008/055505 - a Battery Management System for Lithium Ion Cells

WO/2005/057753 – Method and Apparatus for Multiple Battery Cell

WO/2007/050109 – Lithium Battery Mangement System
WO/2008/045455 – Lithium Battery System
WO/2008/082111- Middle- Or Large-Sized Battery Pack Case Providing Improved
Distribution Uniformity in Coolant Flux
Us20070124980a1 – Cartridge for Middle- Or Large-Sized Battery Pack
Ep20060126328 – Battery Management System and Method
Ep20060026101 - Battery Management System

COMPANY PROFILES

A123SYSTEMS

Advanced Battery Technologies, Inc. (ABAT)

Altair Nanotechnologies

Thunder Sky Battery Limited

Toshiba Battery Co., Ltd.

Valence Technology Inc

APPENDIX I

Table 24 Battery-Powered Electric Vehicles Demonstrated Or Announced By Oems
Using Large-Format Rechargeable Lithium Batteries

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