The Trouble With Lithium Ev World

A Wall Street Journal Business Bestseller “A deeply reported and business-savvy chronicle of Tesla's wild ride.” —Walter Isaacson, New York Times Book Review Power Play is the riveting inside story of Elon Musk and Tesla's bid to build the world's greatest car—from award-winning Wall Street Journal tech and auto reporter Tim Higgins Elon Musk is among the most controversial titans of Silicon Valley. To some he's a genius and a visionary; to others he's a mercurial huckster. Billions of dollars have been gained and lost on his tweets; his personal exploits are the stuff of tabloids. But for all his outrageous talk of mind-uploading and space travel, his most audacious vision is the one closest to the ground: the electric car. When Tesla was founded in the 2000s, electric cars were novelties, trotted out and thrown on the scrap heap by carmakers for more than a century. But where most onlookers saw only failure, a small band of Silicon Valley engineers and entrepreneurs saw opportunity. The gas-guzzling car was in need of disruption. They pitted themselves against the biggest, fiercest business rivals in the world, setting out to make a car that was quicker, sexier, smoother, cleaner than the competition. But as the saying goes, to make a small fortune in cars, start with a big fortune. Tesla would undergo a hellish fifteen years, beset by rivals, pressured by investors, hobbled by whistleblowers, buoyed by its loyal supporters. Musk himself would often prove Tesla's worst enemy—his antics more than once took the company he had initially funded largely with his own money to the brink of collapse. Was he an underdog, an antihero, a conman, or some combination of the three? Wall Street Journal tech and auto reporter Tim Higgins had a front-row seat for the drama: the pileups, wrestling for control, meltdowns, and the unlikeliest outcome of all, success. A story of power, recklessness, struggle, and triumph, Power Play is an exhilarating look at how a team of eccentrics and innovators beat the odds—and changed the future.

A theoretical and technical guide to the electric vehicle lithium-ion battery management system Covers the timely topic of battery management systems for lithium batteries. After introducing the problem and basic background theory, it discusses battery modeling and state estimation. In addition to theoretical modeling it also contains practical information on charging and discharging control technology, cell equalisation and application to electric vehicles, and a discussion of the key technologies and research methods of the lithium-ion power battery management system. The author systematically expounds the theory knowledge included in the lithium-ion battery management systems and its practical application in electric vehicles, describing the theoretical connotation and practical application of the battery management systems. Selected graphics in the book are directly derived from the real vehicle tests. Through comparative analysis of the different system structures and different graphic symbols, related concepts are clear and the understanding of the battery management systems is enhanced. Contents include: key technologies and the difficulty point of vehicle power battery management system; lithium-ion battery performance modeling and simulation; the estimation theory and methods of the lithium-ion battery state of charge, state of energy, state of health and peak power; lithium-ion battery charge and discharge control technology; consistent evaluation and equalization techniques of the battery pack; battery management system design and application in electric vehicles. A theoretical and technical guide to the electric vehicle lithium-ion battery management system Using simulation technology, schematic diagrams and case studies, the basic concepts are described clearly and offer detailed analysis of battery charge and discharge control principles Equips the reader with the understanding and concept of the power battery, providing a clear cognition of the application and management of lithium ion batteries in electric vehicles Arms audiences with lots of case studies Essential reading for Researchers and professionals working in energy technologies, utility planners and system engineers.

As the result of growing concerns of climate change and sustainability, the move to electric vehicles is well under way. Those in the market for a new car are increasingly showing interest in going electric. Yet many car buyers continue to be confused and uneasy about whether a car that runs on batteries alone could meet their needs. Despite their ever-increasing numbers, most people have little or no experience riding in or driving an electric vehicle (EV). As a result, people have questions about EVs, such as: Would an EV's limited driving range meet my day-to-day needs? Are lithium-ion batteries safe? How do the costs of electricity and gasoline compare? What do maintenance costs look like, including replacing the battery? Are they really better for the earth? Unless you follow the industry closely or already drive an EV, you probably don't know enough about the technology's potential and the charging infrastructure to know how well an EV would meet your needs. Between various media sources, there is a great deal of information currently available about the technology. However, much of it is biased - either advocating for or against EVs. And some resources are simply too technical for most people. The many benefits that are driving the EV market are real and important. They produce no tailpipe emissions, and they can effectively help the fight against climate change through ultra-efficient use of electricity -- all while providing an amazing driving experience. EVs also provide lower fuel and maintenance costs. But they still take a long time to charge, the stations to charge them are not yet as common as gas stations and their purchase price is often substantially higher than comparably sized conventional vehicles. Because of this and other less obvious issues, first-time EV buyers need clear, unbiased and relevant information to help them make an informed decision about whether to purchase their first EV. That is why we wrote this book - we see a clear need and opportunity to provide relevant information on EVs in an accurate, objective and easy-to-understand way. Our book, Should I Go Electric? How to Decide if an Electric Vehicle is Right for You, was written specifically to educate and inform readers, dispelling the many misconceptions the public has about EVs. Should I

Go Electric? takes readers from confused and uneasy to informed and confident consumers when making that important decision of choosing their next vehicle.
Advances in Battery Technologies for Electric Vehicles provides an in-depth look into the research being conducted on the development of more efficient batteries capable of long distance travel. The text contains an introductory section on the market for battery and hybrid electric vehicles, then thoroughly presents the latest on lithium-ion battery technology. Readers will find sections on battery pack design and management, a discussion of the infrastructure required for the creation of a battery powered transport network, and coverage of the issues involved with end-of-life management for these types of batteries. Provides an in-depth look into new research on the development of more efficient, long distance travel batteries Contains an introductory section on the market for battery and hybrid electric vehicles Discusses battery pack design and management and the issues involved with end-of-life management for these types of batteries
The number of electric vehicles (cars, buses, e-bikes, electric scooters and electric motorcycles) sold in the Nordic countries is currently increasing quickly. That means that more electricity is used for driving, and also that more of some important metals are being used than earlier. This report regards the fate of the lithium-ion batteries used in vehicles in the Nordic countries. Currently the “Battery Directive” (EC, 2006) which is a producer’s responsibility directive, is under revision and this study is a knowledge base intended for use by the Nordic Environmental Protection Agencies for their referral response in the revision process. This report focuses on the aspect of metal resources, but it does not elaborate on a broader range of environmental impacts, as these were outside the scope of this study.
Lithium Batteries: Science and Technology is an up-to-date and comprehensive compendium on advanced power sources and energy related topics. Each chapter is a detailed and thorough treatment of its subject. The volume includes several tutorials and contributes to an understanding of the many fields that impact the development of lithium batteries. Recent advances on various components are included and numerous examples of innovation are presented. Extensive references are given at the end of each chapter. All contributors are internationally recognized experts in their respective specialty. The fundamental knowledge necessary for designing new battery materials with desired physical and chemical properties including structural, electronic and reactivity are discussed. The molecular engineering of battery materials is treated by the most advanced theoretical and experimental methods.
When the world’s environmental woes get you down, turn to Ecoholic – Canada’s best resource for practical tips and products that help you do your part for the earth. You’ll get the dirt on what not to buy and why, and the dish on great gifts, clothes, home supplies and more. Based on the popular and authoritative "Ecoholic" column that appears weekly in NOW, Ecoholic is a cheeky and eye-opening guide to all of life’s greenest predicaments. The Best

Green Products For the home: cleaning and laundry supplies, furniture, linens For renovations: flooring, paint, insulation, carpets, cabinetry For the kitchen: cookware, appliances For your body: cool clothes, jewellery, shoes, beauty care For baby: toys, cribs, organic food, diapers For the garden: fertilizer, pest control, patio furniture For the office: supplies, equipment, energy savings For your pet: natural food, flea control, litter solutions For the fun of it: sporting goods, camping equipment, holidays The Most Current Information Avoiding toxins in the home Buying pesticide-free food Sustainable seafood, meat and veggie choices Reducing energy and water use Greening your love life Eco-tourism Keeping your home and garden pest-free without harmful chemicals Green gift-giving and ethical investing Choosing an environmentally friendly career The big issues facing Canada and how to get involved The Most Helpful Services Electronics and computer recyclers Alternative energy suppliers Green general stores Local organic food delivery Incentives and rebates for greening your home Local and national environmental groups Household hazardous waste disposal Also includes a city-by-city guide: Calgary, Halifax, Montreal, Ottawa, Toronto, Vancouver, Winnipeg

This book surveys state-of-the-art research on and developments in lithium-ion batteries for hybrid and electric vehicles. It summarizes their features in terms of performance, cost, service life, management, charging facilities, and safety. Vehicle electrification is now commonly accepted as a means of reducing fossil-fuels consumption and air pollution. At present, every electric vehicle on the road is powered by a lithium-ion battery. Currently, batteries based on lithium-ion technology are ranked first in terms of performance, reliability and safety. Though other systems, e.g., metal-air, lithium-sulphur, solid state, and aluminium-ion, are now being investigated, the lithium-ion system is likely to dominate for at least the next decade – which is why several manufacturers, e.g., Toyota, Nissan and Tesla, are chiefly focusing on this technology. Providing comprehensive information on lithium-ion batteries, the book includes contributions by the world's leading experts on Li-ion batteries and vehicles.

Lithium-ion batteries are the most promising among the secondary battery technologies, for providing high energy and high power required for hybrid electric vehicles (HEV) and electric vehicles (EV). Lithium-ion batteries consist of conventional graphite or lithium titanate as anode and lithium transition metal-oxides as cathode. A lithium salt dissolved in an aprotic solvent such as ethylene carbonate and diethylene carbonate is used as electrolyte. This rechargeable battery operates based on the principle of electrochemical lithium insertion/re-insertion or intercalation/de-intercalation during charging/discharging of the battery. It is essential that both electrodes have layered structure which should accept and release the lithium-ion. In advanced lithium-ion battery technologies, other than layered anodes are also considered. High cell voltage, high capacity as well as energy density, high Columbic efficiency, long cycle life, and convenient to fabricate any size or shape of the battery, are the vital features of this battery technology. Lithium-ion batteries are already being used widely in most of the consumer electronics such as mobile phones, laptops, PDAs etc. and are in early stages of application in HEV and EV, which will have far and wide implications and benefits to society. The book contains ten chapters, each focusing on a specific topic pertaining to the application of lithium-ion batteries in Electric Vehicles. Basic principles, electrode materials, electrolytes, high voltage cathodes, recycling spent Li-ion batteries and battery charge controller are addressed. This book is unique among the countable books focusing on the lithium-ion battery technologies for vehicular applications. It provides fundamentals and practical knowledge on the lithium-ion battery for vehicular application. Students, scholars, academicians, and battery and automobile industries will find this volume useful.

This study by the National Research Council (NRC) was requested by DOE's Office of Advanced Automotive Technologies. The study focuses on the processes used by the USABC to select, evaluate, and manage R&D projects on EV batteries in Phases I and II of the program.

This project involved the synthesis of nanowire ã-MnO_2 and characterization as cathode material for high-power lithium-ion batteries for EV and HEV applications. The nanowire synthesis involved the edge site decoration nanowire synthesis developed by Dr. Reginald Penner at UC Irvine (a key collaborator in this project). Figure 1 is an SEM image showing ã-MnO_2 nanowires electrodeposited on highly oriented pyrolytic graphite (HOPG) electrodes. This technique is unique to other nanowire template synthesis techniques in that it produces long (>500 um) nanowires which could reduce or eliminate the need for conductive additives due to intertwining of fibers. Nanowire cathode for lithium-ion batteries with surface areas 100 times greater than conventional materials can enable higher power batteries for electric vehicles (EVs) and hybrid electric vehicles (HEVs). The synthesis of the ã-MnO_2 nanowires was successfully achieved. However, it was not found possible to co-intercalate lithium directly in the nanowire synthesis. Based on input from proposal reviewers, the scope of the project was altered to attempt the conversion into spinel $LiMn_2O_4$ nanowire cathode material by solid state reaction of the ã-MnO_2 nanowires with $LiNO_3$ at elevated temperatures. Attempts to perform the conversion on the graphite template were unsuccessful due to degradation of the graphite apparently caused by oxidative attack by $LiNO_3$. Emphasis then shifted to quantitative removal of the nanowires from the graphite, followed by the solid state reaction. Attempts to quantitatively remove the nanowires by several techniques were unsatisfactory due to co-removal of excess graphite or poor harvesting of nanowires. Intercalation of lithium into ã-MnO_2 electrodeposited onto graphite was demonstrated, showing a partial demonstration of the ã-MnO_2 material as a lithium-ion battery cathode material. Assuming the issues of nanowires removal can be solved, the technique does offer potential for creating high-power lithium-ion battery cathode needed for advanced EV and HEVs. Several technical advancements will still be required to meet this goal, and are likely topics for future SBIR feasibility studies.

This volume includes 15 papers from the National Academy of Engineering's 2006 U.S. Frontiers of Engineering (USFOE) Symposium held in September 2006. USFOE meetings bring together 100 outstanding engineers (ages 30 to 45) to exchange information about leading-edge technologies in a range of engineering fields. The 2006 symposium covered four topic areas: intelligent software systems and machines, the nano/bio interface, engineering personal mobility for the 21st century, and supply chain management. A paper by dinner speaker Dr. W. Dale Compton, Lillian M. Gilbreth

Distinguished Professor of Industrial Engineering, Emeritus, is also included. The papers describe leading-edge research on commercializing auditory neuroscience, future developments in bionanotechnology, sustainable urban transportation, and managing disruptions to supply chains, among other topics. Appendixes include information about contributors, the symposium program, and a list of meeting participants. This is the twelfth volume in the USFOE series.

Lithium batteries may hold the key to an environmentally sustainable, oil-independent future. From electric cars to a "smart" power grid that can actually store electricity, letting us harness the powers of the sun and the wind and use them when we need them, lithium—a metal half as dense as water, found primarily in some of the most uninhabitable places on earth—has the potential to set us on a path toward a low-carbon energy economy. In Bottled Lightning, the science reporter Seth Fletcher takes us on a fascinating journey, from the salt flats of Bolivia to the labs of MIT and Stanford, from the turmoil at GM to cutting-edge lithium-ion battery start-ups, introducing us to the key players and ideas in an industry with the power to reshape the world. Lithium is the thread that ties together many key stories of our time: the environmental movement; the American auto industry, staking its revival on the electrification of cars and trucks; the struggle between first-world countries in need of natural resources and the impoverished countries where those resources are found; and the overwhelming popularity of the portable, Internet-connected gadgets that are changing the way we communicate. With nearly limitless possibilities, the promise of lithium offers new hope to a foundering American economy desperately searching for a green-tech boom to revive it.

The papers included in this issue of ECS Transactions were originally presented in the symposium ¿Rechargeable Lithium and Lithium Ion Batteries¿, held during the 212th meeting of The Electrochemical Society, in Washington, DC, from October 7 to 12, 2007.

Lithium air rechargeable batteries are the best candidate for a power source for electric vehicles, because of their high specific energy density. In this book, the history, scientific background, status and prospects of the lithium air system are introduced by specialists in the field. This book will contain the basics, current statuses, and prospects for new technologies. This book is ideal for those interested in electrochemistry, energy storage, and materials science.

The market for electrified light-duty vehicles (also called passenger vehicles; including passenger cars, pickup trucks, SUVs, and minivans) has grown since the 1990s. During this decade, the first contemporary hybrid-electric vehicle debuted on the global market, followed by the introduction of other types of electric vehicles (EVs). By 2018, electric vehicles made up 4.2% of the 16.9 million new light-duty vehicles sold in the United States that year. Meanwhile, charging infrastructure grew in response to rising electric vehicle ownership, increasing from 3,394 charging stations in 2011 to 78,301 in 2019. However, many locations have sparse or no public charging infrastructure. Electric motors and traction battery packs-most commonly made up of lithium-ion battery cells-set EVs apart from internal combustion engine vehicles (ICEVs). The battery pack provides power to the motor that drives the vehicle. At times, the motor acts as a generator, sending electricity back to the battery. The broad categories of EVs can be identified by whether they have an internal combustion engine (i.e., hybrid vehicles) and

whether the battery pack can be charged by external electricity (i.e., plug-in electric vehicles). The numerous vehicle technologies further determine characteristics such as fuel economy rating, driving range, and greenhouse gas emissions. EVs can be separated into three broad categories: * Hybrid-electric vehicles (HEVs): The internal combustion engine primarily powers the wheels. The battery pack and electric motor provide supplemental power. * Plug-in hybrid-electric vehicles (PHEVs): The battery pack can be charged by an external source of electricity. Depending on the model, primary power to the wheels may be supplied by the battery pack and electric motor, the internal combustion engine, or a combination. * All-electric vehicles (AEVs; also called battery-electric vehicles or BEVs): The battery pack must be charged via an external source of electricity. The battery pack and electric motor power the wheels. Current technology offers three levels of charging for plug-in EVs. Level 1 and Level 2 are currently the most widely accessible with standardized vehicle connectors and charge ports that can be set up for at-home charging. Level 3 (also called DC fast charging) offers the fastest charging rates on the market but is not available for at-home installation due to high voltage. Vehicle connectors and corresponding charge ports for Level 3 are also not standardized, with three different systems currently in use by different vehicle manufacturers. Some research has raised concerns regarding the potential impact of fast charging on battery performance, resulting in technology development aimed at addressing potential capacity loss and decreased charging cycles. As an emergent technology area, EVs present a number of issues for consideration. The fuel sources used to generate the electricity to charge PHEVs and AEVs are a major factor in determining EV greenhouse gas emissions relative to ICEVs. Per-mile EV emissions vary geographically and with the time of day and year that charging takes place. Growing demand for lithium-ion batteries also shifts the material requirements of the vehicle market from fuels for combustion to minerals and other materials for battery production. A growing EV market may encourage new strategies around the supply and refining of raw materials, ability to manufacture batteries, and end-of-life management for batteries that are no longer suitable for use in vehicles.Support for EV deployment stems from, among other things, federal and state policies establishing manufacturing rebates, tax credits for purchases, funding for research and development, and standards for fuel economy and emissions. These policies include the Plug-In Electric Vehicle Tax Credit, and the coordinated Corporate Average Fuel Economy (CAFE) standards and emissions standards for vehicles.
Electric Vehicle Battery Systems provides operational theory and design guidance for engineers and technicians working to design and develop efficient electric vehicle (EV) power sources. As Zero Emission Vehicles become a requirement in more areas of the world, the technology required to design and maintain their complex battery systems is needed not only by the vehicle designers, but by those who will provide recharging and maintenance services, as well as utility infrastructure providers. Includes fuel cell and hybrid vehicle applications. Written with cost and efficiency foremost in mind, Electric Vehicle Battery Systems offers essential details on failure mode analysis of VRLA, NiMH battery systems, the fast-charging of electric vehicle battery systems based on Pb-acid, NiMH, Li-ion technologies, and much more. Key coverage includes issues that can affect electric vehicle performance, such as total battery capacity, battery charging and discharging, and battery temperature constraints. The author also explores electric

vehicle performance, battery testing (15 core performance tests provided), lithium-ion batteries, fuel cells and hybrid vehicles. In order to make a practical electric vehicle, a thorough understanding of the operation of a set of batteries in a pack is necessary. Expertly written and researched, Electric Vehicle Battery Systems will prove invaluable to automotive engineers, electronics and integrated circuit design engineers, and anyone whose interests involve electric vehicles and battery systems. * Addresses cost and efficiency as key elements in the design process * Provides comprehensive coverage of the theory, operation, and configuration of complex battery systems, including Pb-acid, NiMH, and Li-ion technologies * Provides comprehensive coverage of the theory, operation, and configuration of complex battery systems, including Pb-acid, NiMH, and Li-ion technologies

Starting out with an introduction to the fundamentals of lithium ion batteries, this book begins by describing in detail the new materials for all four major uses as cathodes, anodes, separators, and electrolytes. It then goes on to address such critical issues as self-discharge and passivation effects, highlighting lithium ion diffusion and its profound effect on a battery's power density, life cycle and safety issues. The monograph concludes with a detailed chapter on lithium ion battery use in hybrid electric vehicles. Invaluable reading for materials scientists, electrochemists, physicists, and those working in the automobile and electrotechnical industries, as well as those working in computer hardware and the semiconductor industry.

This timely book provides you with a solid understanding of battery management systems (BMS) in large Li-Ion battery packs, describing the important technical challenges in this field and exploring the most effective solutions. You find in-depth discussions on BMS topologies, functions, and complexities, helping you determine which permutation is right for your application. Packed with numerous graphics, tables, and images, the book explains the OC whysOCO and OC howsOCO of Li-Ion BMS design, installation, configuration and troubleshooting. This hands-on resource includes an unbiased description and comparison of all the off-the-shelf Li-Ion BMSs available today. Moreover, it explains how using the correct one for a given application can help to get a Li-Ion pack up and running in little time at low cost."

Lithium Process Chemistry: Resources, Extraction, Batteries and Recycling presents, for the first time, the most recent developments and state-of-the-art of lithium production, lithium-ion batteries, and their recycling. The book provides fundamental and theoretical knowledge on hydrometallurgy and electrochemistry in lithium-ion batteries, including terminology related to these two fields. It is of particular interest to electrochemists who usually have no knowledge in hydrometallurgy and hydrometallurgists not familiar with electrochemistry applied to Li-ion batteries. It is also useful for both teachers and students, presenting an overview on Li production, Li-ion battery technologies, and lithium battery recycling processes that is accompanied by numerous graphical presentations of different battery systems and their electrochemical performances. The book represents the first time that hydrometallurgy and electrochemistry on lithium-ion batteries are assembled in one unique source. Provides fundamental and theoretical knowledge on hydrometallurgy and electrochemistry in lithium-ion batteries Represents the first time that hydrometallurgy and electrochemistry on lithium-ion batteries are assembled in one unique source. Ideal for both electrochemists who usually have no knowledge in hydrometallurgy and hydrometallurgists not familiar with electrochemistry applied to Li-ion batteries Presents recent developments, as well as challenges in lithium production and lithium-ion battery technologies and their recycling Covers examples of Li processes production with schematics, also including numerous graphical presentations of different battery systems and their electrochemical performances

Lithium-Ion Batteries Hazard and Use Assessment examines the usage of lithium-ion batteries and cells within consumer, industrial and transportation products, and analyzes the potential hazards associated with their prolonged use. This book also surveys the applicable codes and standards for lithium-ion technology. Lithium-Ion Batteries Hazard and Use Assessment is designed for practitioners as a reference guide for lithium-ion batteries and cells. Researchers working in a related field will also find the book valuable.

Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market reviews the performance, cost, safety, and sustainability of battery systems for hybrid electric vehicles (HEVs) and electric vehicles (EVs), including nickel-metal hydride batteries and Li-ion batteries. Throughout this book, especially in the first chapters, alternative vehicles with different power trains are compared in terms of lifetime cost, fuel consumption, and environmental impact. The emissions of greenhouse gases are particularly dealt with. The improvement of the battery, or fuel cell, performance and governmental incentives will play a fundamental role in determining how far and how substantial alternative vehicles will penetrate into the market. An adequate recharging infrastructure is of paramount importance for the diffusion of vehicles powered by batteries and fuel cells, as it may contribute to overcome the so-called range anxiety."" Thus, proposed battery charging techniques are summarized and hydrogen refueling stations are described. The final chapter reviews the state of the art of the current models of hybrid and electric vehicles along with the powertrain solutions adopted by the major automakers. Contributions from the worlds leading industry and research experts Executive summaries of specific case studies Information on basic research and application approaches

A comprehensive guide to the reuse and recycling of lithium-ion power batteries—fundamental concepts, relevant technologies, and business models Reuse and Recycling of Lithium-Ion Power Batteries explores ways in which retired lithium ion batteries (LIBs) can create long-term, stable profits within a well-designed business operation. Based on a large volume of experimental data collected in the author’s lab, it demonstrates how LIBs reuse can effectively cut the cost of Electric Vehicles (EVs) by extending the service lifetime of the batteries. In addition to the cost benefits, Dr. Guangjin Zhao discusses how recycling and reuse can significantly reduce environmental and safety hazards, thus complying with the core principles of environment protection: recycle, reuse and reduce. Offering coverage of both the fundamental theory and applied technologies involved in LIB reuse and recycling, the book's contents are based on the simulated and experimental results of a hybrid micro-grid demonstration project and recycling system. In the opening section on battery reuse, Dr. Zhao introduces key concepts, including battery dismantling, sorting, second life prediction, re-packing, system integration and relevant technologies. He then builds on that foundation to explore advanced topics, such as resource recovery, harmless treatment, secondary pollution control, and zero emissions technologies. Reuse and

Recycling of Lithium-Ion Power Batteries: • Provides timely, in-depth coverage of both the reuse and recycling aspects of lithium-ion batteries • Is based on extensive simulation and experimental research performed by the author, as well as an extensive review of the current literature on the subject • Discusses the full range of critical issues, from battery dismantling and sorting to secondary pollution control and zero emissions technologies • Includes business models and strategies for secondary use and recycling of power lithium-ion batteries Reuse and Recycling of Lithium-Ion Power Batteries is an indispensable resource for researchers, engineers, and business professionals who work in industries involved in energy storage systems and battery recycling, especially with the manufacture and use (and reuse) of lithium-ion batteries. It is also a valuable supplementary text for advanced undergraduates and postgraduate students studying energy storage, battery recycling, and battery management.
?This book presents a state-of-the-art review of recent advances in the recycling of spent lithium-ion batteries. The topics covered include: introduction to the structure of lithium-ion batteries; development of battery-powered electric vehicles; potential environmental impact of spent lithium-ion batteries; pretreatment of spent lithium-ion batteries for recycling processing; pyrometallurgical processing for recycling spent lithium-ion batteries; hydrometallurgical processing for recycling spent lithium-ion batteries; direct processing for recycling spent lithium-ion batteries; high value-added products from recycling of spent lithium-ion batteries; and effects of recycling of spent lithium-ion batteries on environmental burdens. The book provides an essential reference resource for professors, researchers, and policymakers in academia, industry, and government around the globe.
"In recent years, many forecasts have predicted a large scale adoption of electric vehicles (EVs), which would predominantly be powered by lithium-ion batteries (LIBs), owing to their high energy and power density and long cycle life. While use of EVs could reduce dependence on fossil based transportation fuels, there is a need to understand the end-of-life (EOL) implications of retired EV LIBs entering the waste stream in future in the battery-driven vehicle regime. To proactively address impending waste management issues and inform related policy, this dissertation explored the sustainable management of LIBs after use in EVs and the challenges and opportunities involved. First, a future oriented, dynamic Material Flow Analysis (MFA) was conducted to estimate the volume of LIB wastes to be potentially generated in the US in near and long term. The objective of tracking future outflows of EOL EV LIBs through the MFA model was to: (a) Provide an understanding of the scale at which EV LIB waste management infrastructure needs to be developed in future, and (b) Analyze the composition of future EV LIB waste stream in terms of constituent LIB packs, cells and materials. The effect of EV adoption scenarios, variability in LIB lifespan distribution, battery energy storage, LIB chemistry and form factor on the volume, recyclability and material value of the forecasted waste stream was analyzed. Because of the potential “lifespan mismatch” between battery packs and EVs, LIBs with high reuse potential are expected in the waste stream. Results of the MFA model projected annual EV LIB waste flows of as high as 340,000 metric

tons by 2040. Apart from the high volume, the projected EV LIB waste streams were characterized by the presence of a variety of recyclable metals, high percentage of non-recyclable materials, high variability in the potential economic value, and potential for battery reuse. Hence, a robust end of life battery management system would include an increase in reuse avenues, expanded recycling capacity, and safe disposal routes accompanied by policy incentives to promote environmentally and economically favorable EOL management of EV LIBs. Second, the environmental trade-offs of cascaded use of retired EV LIBs in stationary energy storage was investigated using cradle-to-grave life cycle assessment (LCA). The LCA model was framed from the dual perspective of stakeholders in the: (a) the EV sector, to understand if there is there a meaningful reduction in EV lithium ion battery environmental impact due to cascaded reuse, and (b) the Energy Utility sector, to understand if the utility sector could environmentally benefit from using refurbished EV lithium ion batteries for energy storage. In both the cases, an environmental benefit was obtained owing to avoiding the production and use of an incumbent lead-acid battery based system. However, there were diminished to no environmental benefits in scenarios where very few of the initial battery cells and modules could be reused and where service life was low in secondary application for refurbished EV LIB cells. Hence, environmental feasibility of cascaded use systems was found to be directly related to technical feasibility and reliability. An important methodological challenge addressed was the allocation of environmental impact associated with production and EOL management of LIBs across the EV and stationary use systems. The allocation modeling choices explored here were based on the concept of closed-loop recycling for material cascades. These modeling approaches can guide LCA of similar product cascade systems where a product is used for a cascaded second use in a different application. Finally, a circular economy-inspired waste management hierarchy was proposed for EOL EVs from LIBs that included limited reuse in EVs, cascaded use in stationary applications, recycling and finally, landfill. To validate this circular economy approach, an eco-efficiency analysis was conducted across proposed waste management strategies for an EV LIB waste stream (modeled as 1,000 battery packs coming out of use in EV applications in the U.S.). Results demonstrated that a circular economy-centric waste management hierarchy can be environmentally and economically effective in managing the EV LIB waste stream in future, owing to benefits from reuse, cascaded use and recycling. However, such benefits would rely significantly on LIB size, testing procedures, the incumbent battery systems that used LIBs would displace, future prices of these batteries, and future recycling costs. Hence, these EOL management strategies would need policy and technology push to be viable. Although much attention has been placed on landfill disposal bans for batteries, results actually indicated that direct and cascaded reuse, followed by recycling can together negate the eco-toxicity burden of unavoidable metal flows into landfill. When combined with regulations deterring landfill and policies promoting life cycle approaches that additionally consider design-for-EOL, battery maintenance, collection and safe transport, circular waste management systems can be improved for these batteries. Overall, a circular waste management system for EV LIBs is likely to complement existing and guide future policies governing EV LIB waste."--Abstract.

This fundamental guide teaches readers the basics of battery design for electric vehicles. Working through this book, you will understand how to optimise battery performance and functionality, whilst minimising costs and maximising durability. Beginning with the basic concepts of electrochemistry, the book moves on to describe implementation, control and management of batteries in real vehicles, with respect to the battery materials. It describes how to select cells and batteries with explanations of the advantages and disadvantages of different battery chemistries, enabling readers to put their knowledge into practice and make informed and successful design decisions, with a thorough understanding of the trade-offs involved. The first of its kind, and written by an industry expert with experience in academia, this is an ideal resource for both students and researchers in the fields of battery research and development as well as for professionals in the automotive industry extending their interest towards electric vehicles.

The emerging applications of electric vehicles (EV) and grid scale energy storage are pushing the limit of energy storage technologies. To meet the US Department of Energy (DOE)'s targets for EV batteries and grid storage, battery chemistries beyond the current lithium ion systems are required. Among the many new chemistries studied, lithium sulfur battery is one of the most promising technologies that could have high specific energy and low cost. In this thesis, I will examine the main challenges in lithium sulfur batteries and present my study on using nanoscale engineering approaches to address the problems of both the sulfur cathode and the lithium metal anode. Lithium sulfur battery has a theoretical specific energy of around 2600 Wh/kg, around 10 times that of the current lithium ion battery technology. The large abundance of sulfur also means that battery cost can be significantly reduced by replacing the expensive transition metals used in conventional lithium ion batteries. However, sulfur is a highly insulating material and the intermediate discharge products lithium polysulfides can easily dissolve into the electrolyte. In the first part of my study, I will describe my work on using nanostructure materials to improve the sulfur cathode performance. By using nanostructure design, sulfur can be embedded into nanoscale conductive matrix, which significantly improve the sulfur utilization and reduce the polysulfide dissolution. We demonstrated that high specific capacity of around 1400 mAh/g could be achieved using the hollow carbon nanofiber encapsulated sulfur cathode structure. I will also present my study on the interfacial properties in the sulfur cathode, their potential effect on the initial capacity decay and our solutions to address the problem. The change in binding strength between the sulfur cathode and the conductive carbon matrix was

observed using ex-situ¬ TEM study. We tackle this problem by functionalizing the carbon surface with amphiphilic polymers that allow anchoring of the polar lithium sulfides species to the non-polar carbon surface. We also used a patterned surface to confirm this phenomenon, by demonstrating controlled spatial deposition of lithium sulfide. Based on the study, we fabricated a hybrid electrode consisting of metal oxide particles decorated carbon nanofiber current collectors, which show marked improvement in stabilizing the sulfur cathode performance. For the anode side, I will present my research on using nanoscale engineering approach to improve the lithium metal anode. Lithium metal has long been considered the "holy grail" in lithium battery research, due to its high specific capacity and the lowest potential among all lithium anode materials. However, the problems of lithium dendrite formation and low cycling Coulombic efficiency have prevented lithium metal anode from successful application. By introducing a nanoscale interfacial layer of interconnected hollow carbon spheres onto the lithium surface, we demonstrate that lithium dendrite formation can be largely suppressed at a practical current density and the cycling Coulombic efficiency significantly improved. Our work provides a new direction in addressing the long-standing lithium metal problems. I will also talk about the semi-liquid flow battery design for grid storage, by paring lithium polysulfide catholyte with lithium metal. The energy density and power density can be potentially decoupled in the semi-liquid flow batteries. The catholyte (lithium polysulfide solution) can be stored in an external tank and pumped into the battery chamber on demand. The system has a very high energy density of around 170 Wh/kg (190 Wh/L), with an impressive cycle life of more than 2400 cycles at constant capacity charging of 200 mAh/g.
Addresses the methodology and theoretical foundation of battery manufacturing, service and management systems (BM2S2), and discusses the issues and challenges in these areas This book brings together experts in the field to highlight the cutting edge research advances in BM2S2 and to promote an innovative integrated research framework responding to the challenges. There are three major parts included in this book: manufacturing, service, and management. The first part focuses on battery manufacturing systems, including modeling, analysis, design and control, as well as economic and risk analyses. The second part focuses on information technology’s impact on service systems, such as data-driven reliability modeling, failure prognosis, and service decision making methodologies for battery services. The third part addresses battery management systems (BMS) for control and optimization of battery cells, operations, and hybrid storage systems to ensure overall performance and safety, as well as EV management. The contributors consist of experts from universities, industry research centers, and government agency. In addition, this book: Provides comprehensive overviews of lithium-ion battery and battery electrical vehicle manufacturing, as well as economic returns and government support Introduces integrated models for quality propagation and productivity

improvement, as well as indicators for bottleneck identification and mitigation in battery manufacturing Covers models and diagnosis algorithms for battery SOC and SOH estimation, data-driven prognosis algorithms for predicting the remaining useful life (RUL) of battery SOC and SOH Presents mathematical models and novel structure of battery equalizers in battery management systems (BMS) Reviews the state of the art of battery, supercapacitor, and battery-supercapacitor hybrid energy storage systems (HESSs) for advanced electric vehicle applications Advances in Battery Manufacturing, Services, and Management Systems is written for researchers and engineers working on battery manufacturing, service, operations, logistics, and management. It can also serve as a reference for senior undergraduate and graduate students interested in BM2S2.

"A worldwide race is on to perfect the next engine of economic growth, the advanced lithium-ion battery. It will power the electric car, relieve global warming, and catapult the winner into a new era of economic and political mastery. Can the United States win? Steve LeVine was granted unprecedented access to a secret federal laboratory outside Chicago, where a group of geniuses is trying to solve this next monumental task of physics. But these scientists-- almost all foreign born--are not alone. With so much at stake, researchers in Japan, South Korea, and China are in the same pursuit. The drama intensifies when a Silicon Valley start-up licenses the federal laboratory's signature invention with the aim of a blockbuster sale to the world's biggest carmakers. The Powerhouse is a real-time, twoyear thrilling account of big invention, big commercialization, and big deception. It exposes the layers of competition and ambition, aspiration and disappointment behind this great turning point in the history of technology"--Provided by publisher.

Electrolytes for Lithium and Lithium-ion Batteries provides a comprehensive overview of the scientific understanding and technological development of electrolyte materials in the last several years. This book covers key electrolytes such as $LiPF_6$ salt in mixed-carbonate solvents with additives for the state-of-the-art Li-ion batteries as well as new electrolyte materials developed recently that lay the foundation for future advances. This book also reviews the characterization of electrolyte materials for their transport properties, structures, phase relationships, stabilities, and impurities. The book discusses in-depth the electrode-electrolyte interactions and interphasial chemistries that are key for the successful use of the electrolyte in practical devices. The Quantum Mechanical and Molecular Dynamical calculations that has proved to be so powerful in understanding and predicating behavior and properties of materials is also reviewed in this book. Electrolytes for Lithium and Lithium-ion Batteries is ideal for electrochemists, engineers, researchers interested in energy science and technology, material scientists, and physicists working on energy.

The notion of 'creative cities' - where cultural activities and creative and cultural industries play a crucial role in supporting urban creativity and contributing to the

new creative economy - has become central to most regional and urban development strategies in recent years. A creative city is supposed to develop imaginative and innovative solutions to a range of social, economic and environmental problems: economic stagnancy, urban shrinkage, social segregation, global competition or more. Cities and regions around the world are trying to develop, facilitate or promote concentrations of creative, innovative and/or knowledge-intensive industries in order to become more competitive. These places are seeking new strategies to combine economic development with quality of place that will increase economic productivity and encourage growth. Against this increasing interest in creative cities, this volume offers a coherent set of articles on sustainable and creative cities, and addresses modern theories and concepts relating to research on sustainability and creativity. It analyses principles and practices of the creative city for the formulation of policies and recommendations towards the sustainable city. It brings together leading academics with different approaches from different disciplines to provide a comprehensive and holistic overview of creativity and sustainability of the city, linking research and practice. In doing so, it puts forward ideas about stimulating the production of an innovative knowledge for a creative and sustainable city, and transforming a specific knowledge into a general common knowledge, which suggests best future policy actions, decision-making processes and choices for the change towards a human sustainable development of the city.
Accelerated development and market penetration of plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs) is restricted at present by the high cost of lithium-ion (Li-ion) batteries. One way to address this problem is to recover a fraction of the Li-ion battery's cost via reuse in other applications after it is retired from service in the vehicle, when the battery may still have sufficient performance to meet the requirements of other energy storage applications.
Lithium-Ion Batteries features an in-depth description of different lithium-ion applications, including important features such as safety and reliability. This title acquaints readers with the numerous and often consumer-oriented applications of this widespread battery type. Lithium-Ion Batteries also explores the concepts of nanostructured materials, as well as the importance of battery management systems. This handbook is an invaluable resource for electrochemical engineers and battery and fuel cell experts everywhere, from research institutions and universities to a worldwide array of professional industries. Contains all applications of consumer and industrial lithium-ion batteries, including reviews, in a single volume Features contributions from the world's leading industry and research experts Presents executive summaries of specific case studies Covers information on basic research and application approaches
The purpose of this thesis is to assess -from a life cycle perspective - the environmental benefits of re-purposing electric vehicle Li-ion batteries to re-use in stationary applications. The thesis consists of three separate papers arranged in as chapters. The main objectives are threefold: to develop and analyze a parameterized life cycle model of Li-ion battery first use in EV and extended usage to incorporate the re-purposing and re-use in grid storage for a utility application (Chapter 3), to evaluate effective factors on

the feasibility of re-purposing used EV Li-ion batteries and the effect of factors on the cumulative energy use and greenhouse gas (GHG) emissions of the re-purposed batteries life cycle (Chapter 4)., and to assess potential environmental impacts of re-purposing and re-using of EV Li-ion batteries into stationary applications from a life cycle perspective and compare with natural gas stationary power generation (Chapter 5). According to the study, it is found that the magnitude of CO2 mitigation associated with battery re-use is similar to that of switching from using a conventional vehicle to an electric vehicle, meaning that the GHG benefits of vehicle electrification could be doubled by extending the life of EV batteries, and better using off-peak low-cost clean electricity. the effects of capacity fade, energy efficiency fade, failure rate, and charge/discharge profile are investigated for Li-ion batteries based on first use in EVs and second-use in ESS. It is estimated that the re-purposed EV battery loses a further 15% of its capacity after its second use in the energy storage system (ESS) over 10 years. As energy efficiency decreases with increased charge/discharge cycles, a capacity fade model is used to approximate the effect of the relationship between cycles and capacity fade over the life of the battery. The performance of the iiii battery in its second use is represented using a model of degradation modes, assuming a 0.01% cell failure rate and a non-symmetric charge/discharge profile. Finally, an accurate modeling of battery performance is used to examine energy savings and GHG emission reduction benefits from using a Li-ion battery first in an EV and then in an ESS connected to the Ontario electrical grid. A cradle-to-grave life cycle assessment (LCA) of the Li-ion battery pack is conducted and six environmental impact categories are assessed including global warming potential, particulate matter formation, freshwater eutrophication, photochemical oxidant formation potential, metal depletion, and fossil depletion. It is concluded that the manufacturing phase of the Li-ion battery has the main environmental impacts during the life cycle of the battery as concluded from. Utilizing the re-purposed Li-ion battery in contrast with natural gas source in the stationary application powering causes more savings from an environmental standpoint. The assessed environmental impacts highlight the importance of electricity mix used in the processes of the product systems. Finally, the effect of the battery degradation is analyzed through energy efficiency fade effect on the battery performance and it is found that the use phase of the battery in the EV during 8 years is more sensitive to this phenomenon than the re-using of the Li-ion batteries in the stationary application during additional 10 years.
A real-world guide for adapting to the new energy era The Energy Disruption Triangle is a treatise on the energy revolution’s real-world impacts, and a handbook for anyone looking to weather the storm. Three major technologies are already changing the energy paradigm: solar energy, electric vehicles, and energy storage. As technology continues to evolve and become more accessible to the masses, the nation’s energy habits will experience a dramatic upheaval; this book provides actionable guidance to help you adapt. We are already in the beginning stages of this black swan event, and most people don’t know what’s coming—but it will come much sooner and much faster than anyone thinks. This book reveals the revolution happening right before our eyes, and shows you how to thrive in this new era. Learn how our energy supplies—and usage—are changing Understand why energy storage matters, and how the technology is evolving Explore the history and future of groundbreaking energy technologies Delve

into the disruption of the U.S. energy supply, and the possibility of energy independence Rapidly advancing battery technology is boosting energy storage for homeowners, utilities, and electric vehicle manufacturers, stranding fossil fuels in the ground due to the high price of extraction relative to cost-effective sources such as solar and wind. Traditional energy sources are being phased out, and our nation has come to a fork in the road: uphold the status quo and allow our energy supply to be disrupted, or adapt and advance to a state of total energy independence. The Energy Disruption Triangle explores the state of U.S. energy from source to consumer, and provides insight into the three sectors that are changing the world.

This handbook serves as a guide to deploying battery energy storage technologies, specifically for distributed energy resources and flexibility resources. Battery energy storage technology is the most promising, rapidly developed technology as it provides higher efficiency and ease of control. With energy transition through decarbonization and decentralization, energy storage plays a significant role to enhance grid efficiency by alleviating volatility from demand and supply. Energy storage also contributes to the grid integration of renewable energy and promotion of microgrid.

The lithium ion system considered in this report uses lithium intercalation compounds as both positive and negative electrodes and has an organic liquid electrolyte. Oxides of nickel, cobalt, and manganese are used in the positive electrode, and carbon is used in the negative electrode. This report presents health and safety issues, environmental issues, and shipping requirements for lithium ion electric vehicle (EV) batteries. A lithium-based electrochemical system can, in theory, achieve higher energy density than systems using other elements. The lithium ion system is less reactive and more reliable than present lithium metal systems and has possible performance advantages over some lithium solid polymer electrolyte batteries. However, the possibility of electrolyte spills could be a disadvantage of a liquid electrolyte system compared to a solid electrolyte. The lithium ion system is a developing technology, so there is some uncertainty regarding which materials will be used in an EV-sized battery. This report reviews the materials presented in the open literature within the context of health and safety issues, considering intrinsic material hazards, mitigation of material hazards, and safety testing. Some possible lithium ion battery materials are toxic, carcinogenic, or could undergo chemical reactions that produce hazardous heat or gases. Toxic materials include lithium compounds, nickel compounds, arsenic compounds, and dimethoxyethane. Carcinogenic materials include nickel compounds, arsenic compounds, and (possibly) cobalt compounds, copper, and polypropylene. Lithiated negative electrode materials could be reactive. However, because information about the exact compounds that will be used in future batteries is proprietary, ongoing research will determine which specific hazards will apply.

This book addresses recycling technologies for many of the valuable and scarce materials from spent lithium-ion batteries. A successful transition to electric mobility will result in large volumes of these. The book discusses engineering issues in the entire process chain from disassembly over mechanical conditioning to chemical treatment. A framework for environmental and economic evaluation is presented and recommendations for researchers as well as for potential operators are derived.

Lithium solid polymer electrolyte (SPE) batteries are being investigated by researchers worldwide as a possible energy source for future electric vehicles (EVs). One of the main reasons for interest in lithium SPE battery systems is the potential safety features they offer as compared to lithium battery systems using inorganic and organic liquid electrolytes. However, the development of lithium SPE batteries is still in its infancy, and the technology is not envisioned to be ready for commercialization for several years. Because the research and development (R & D) of lithium SPE battery technology is of a highly competitive nature, with many companies both in the United States and abroad pursuing R & D efforts, much of the information concerning specific developments of lithium SPE battery technology is proprietary. This report is based on information available only through the open literature (i.e., information available through library searches). Furthermore, whereas R & D activities for lithium SPE cells have focused on a number of different chemistries, for both electrodes and electrolytes, this report examines the general environmental, health, and safety (EH & S) issues common to many lithium SPE chemistries. However, EH & S issues for specific lithium SPE cell chemistries are discussed when sufficient information exists. Although lithium batteries that do not have a SPE are also being considered for EV applications, this report focuses only on those lithium battery technologies that utilize the SPE technology. The lithium SPE battery technologies considered in this report may contain metallic lithium or nonmetallic lithium compounds (e.g., lithium intercalated carbons) in the negative electrode.