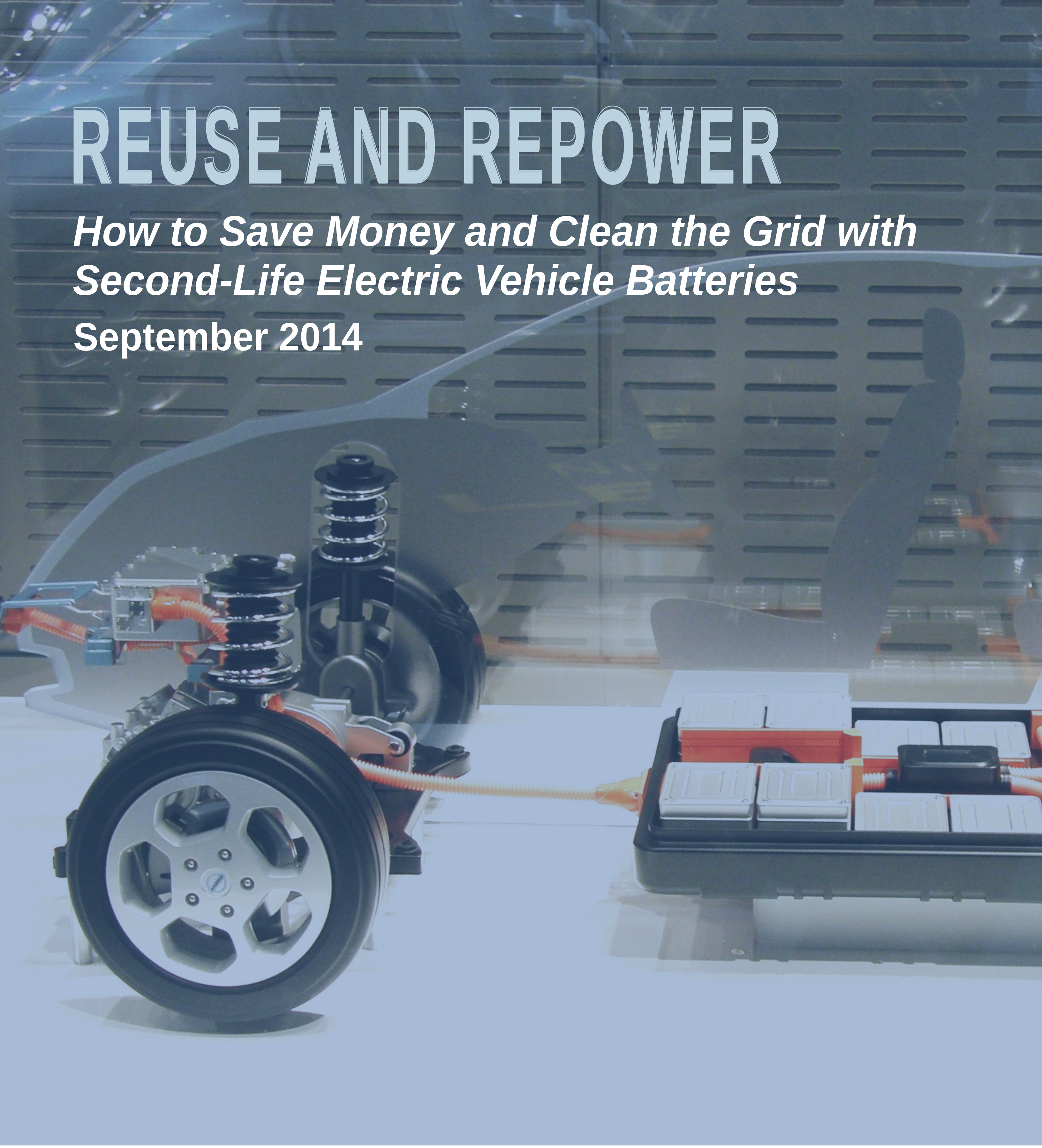

REUSE AND REPOWER

How to Save Money and Clean the Grid with Second-Life Electric Vehicle Batteries

September 2014

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About this Report

This policy paper is the thirteenth in a series of reports on how climate change will create opportunities for specific sectors of the business community and how policy-makers can facilitate those opportunities. Each paper results from one-day workshop convenings that include representatives from key business, academic, and policy sectors of the targeted industries. The convenings and resulting policy papers are sponsored by Bank of America and produced by a partnership of the UCLA School of Law's Emmett Institute on Climate Change and the Environment and UC Berkeley School of Law's Center for Law, Energy & the Environment.

Authorship

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Acknowledgments

The author and organizers are grateful to Bank of America for its generous sponsorship of the Climate Change and Business Research Initiative. We would specifically like to thank Catherine P. Bessant, Global Technology and Operations Executive and Chair of the Bank of America Environmental Council, for her commitment to this work.

In addition, we are grateful to Tuong-Vi Faber at UC Berkeley School of Law for her research and drafting support, Jayesh D'Souza for additional research, Claire Hermann for designing this policy report, and Summer Rose of the UCLA School of Law for coordinating the convening.

Finally, the UC organizers gratefully acknowledge Renata Arsenault, Shouvik Banerjee, Paul Beach, Brian Dillard, Bruce Falls, Mike Ferry, Robert (Bob) L. Galyen, Gopal Garg, Ryan Harty, Armando Infanzon, Adam Langton, Ryan McCarthy, Michael Moyer, David N. Patterson, Beth Reid, Bradley Smith, Jr., Dirk Spiers, Dean Taylor, John Tillman, Ichiro Sugioka, Pablo Valencia, Byron Washom and Randall Winston for their insight and commentary at the April 28, 2014 convening that informed this analysis.

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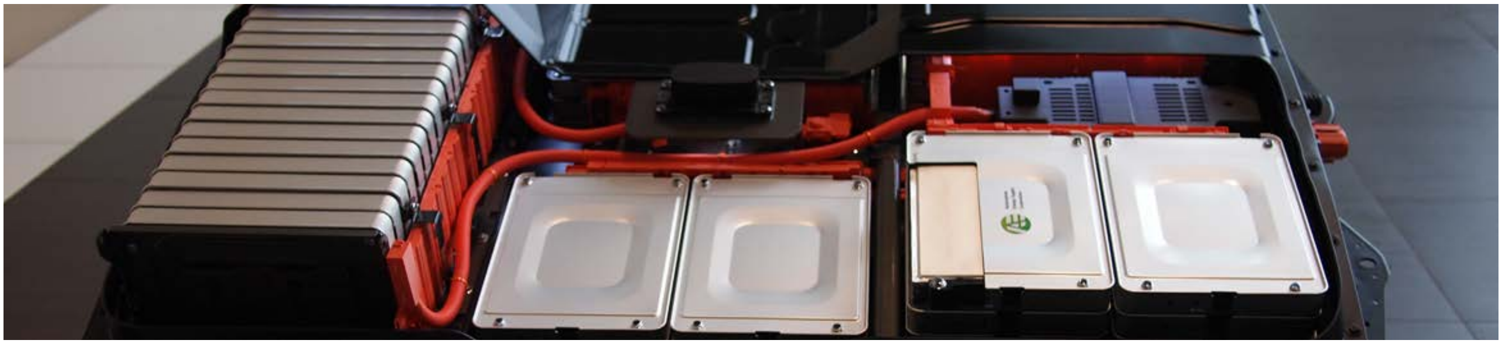


Introduction and Summary: A Path Forward for Second Life Batteries

California is experiencing a surge in renewable energy generation from the sun and wind. But the state will face long-term economic and environmental challenges relying on these intermittent resources without deploying more energy storage, such as batteries, compressed air, and pumped hydro facilities. Of the options available, only large-scale energy storage technologies can capture enough surplus renewable energy during times of low demand for later dispatch at the scale needed to decarbonize our electricity supply over the coming decades.

Used electric vehicle batteries could be a critical – and inexpensive – part of the solution. As sales of electric vehicles in the United States head toward a quarter million, with over 40 percent of those purchases in California, the thousands of batteries that will be coming out of the vehicles in the coming years will still retain significant capacity, although not enough to provide a sufficient electric driving range. Assuming 50 percent of the battery packs on the road in 2014 can be repurposed, with 75 percent of their original capacity, these second-life batteries could store and dispatch up to 850 megawatt hours of electricity (one megawatt hour is roughly equivalent to the amount of electricity used by about 330 homes over one hour). The aggregated capacity is also equal to 425 megawatts worth of power (one megawatt can provide sufficient power in any given moment to approximately 750 households) – almost one-third of the energy storage capacity that utilities are required to procure by 2020 under a recent California mandate.

Property owners, developers, and utilities could harness energy storage from these inexpensive used batteries in a “second life” to help integrate variable renewables and save electricity costs. Private companies and research institutions have already initiated pilot vehicle battery storage programs, aggregating multiple used batteries to develop a bulk, commercial-scale energy storage system and microgrid backup system, among other demonstrations. Second-life batteries could also provide backup power for homes and businesses and save owners electricity costs. In addition, utilities could dispatch peak power from these distributed batteries to relieve expensive fossil fuel-burning power plants and compensate for decreases in renewable energy supply.

In the near term, the residual value of second-life batteries could help lower upfront electric vehicle costs, as automakers and consumers alike factor in the resale value as part of a reduced purchase price. Preliminary studies indicate, for example, that a used 24 kilowatt hour Nissan LEAF battery could net the vehicle owner up to $2,400 in resale value, while a Tesla Model S owner could sell the 85 kilowatt hour battery pack for up to $8,500. Lower upfront prices from this future revenue mean greater adoption of these vehicle technologies that can dramatically reduce air pollution and save consumers money over the life of the vehicles.

To develop a vision and policies for second-life electric vehicle battery deployment, automakers, utilities representatives, energy storage developers, business leaders, and public officials gathered at the University of California, Los Angeles in April 2014 for a discussion sponsored by the University of California Berkeley and Los Angeles Schools of Law. The group envisioned expanded second-life battery deployment opportunities and suggested strategies and policies to begin developing a market for these batteries.

Ultimately, the group envisioned a thriving future market for second-life batteries, taking advantage of the lower cost and remaining battery life for a range of applications. The reuse of these batteries in the coming decades will help California achieve its renewable energy, energy storage, and greenhouse gas reduction goals in a more cost-effective manner while reducing the cost of electric vehicle ownership.

4 Key Barriers to Realizing this Vision

1) Economic uncertainty about second-life battery value translating to reduced upfront costs for electric vehicle consumers;
2) Complex and adverse regulatory structures that limit market opportunities and increase costs;
3) Liability concerns about which entity is responsible for second-life batteries once they complete their first life in the vehicle; and
4) Lack of data about battery performance in both first and second life applications.

Solutions to Overcome the Barriers

- Improved and expanded second-life battery pilot projects to demonstrate market potential
- An industry-led regulatory working group to identify and address regulatory conflicts and needs that limit market development
- Industry-developed technical performance standards for second-life battery certification that policy makers can use to clarify product liability
- Increased funding and incentives for data collection and dissemination on second-life battery projects

The following section summarizes the policies that are discussed in greater detail in this report, which also contains an overview of second-life batteries and the policies that affect their deployment.

Federal & State Leaders

Encourage more second-life battery demonstration projects by improving grant support and reducing administrative barriers to implementation.
Government agencies that offer grants and other support for pilot projects should streamline the proposal and reporting process and encourage more innovative private sector involvement.

Reform regulations that prevent second-life battery pilot projects from accessing specific grid markets.
Utilities and grid operators should allow pilot projects temporary access to the grid and relevant markets to test their services.

Offer tax credits, rebates, and other financial incentives for the most promising second-life demonstration efforts.
Public sector financial support, at least to cover part of second-life battery project costs, can make the difference in getting a demonstration launched and would help facilitate market innovation.

Fund expert-led effort to inventory, monitor and address the most pressing federal and state regulations that affect second-life battery deployment.

Experts on regulatory policy should assess the current regulations, regulatory gaps, and projected future of regulation, as well as ongoing regulatory needs given various possible ownership models over multiple stages of use.

Commit to developing clear and consistent regulations governing second-life batteries over specified time lines.
A five- or ten-year period following 2018 that avoids changing the basic rules governing second-life batteries would help encourage market development.

Ensure that grid-related incentive programs include second-life batteries as eligible.
Second-life or used batteries are currently ineligible for California's Self-Generation Incentive Program as well as the federal Investment Tax Credit.

Ensure that carbon and grid regulations account for the potential of second-life batteries.
As federal and state leaders develop policies to reduce carbon pollution, integrate renewable energy, and boost energy storage deployment generally, they should consider the multiple benefits that second-life batteries could provide.

State Legislators & Agency Leaders

Improve the quality and market relevance of second-life battery demonstration projects.
Agency and industry leaders should collaborate to develop more market-ready pilot projects, including incentives to encourage business participation.

Fund research, possibly through the California Energy Commission, to inventory and map the most pressing state regulations affecting second-life battery deployment in California.
As discussed above, experts on state regulatory policy should assess the regulations that promote or hinder deployment, based on various possible ownership models over multiple stages of use.

Make available utility, government, and grid data to help industry actors understand second-life revenue opportunities in promising second-life applications, via a third party database with incentives for participation.
California grid operators and utilities should provide energy data to an independent, transparent database on promising second-life applications to give investors an opportunity to gauge potential revenue and costs.

Focus on collecting performance data from second-life battery pilot projects with funding for this purpose.
Universities, national laboratories and other entities engaging in this research, including for various applications like microgrids, should make their project-level data easily available to third parties, with funding from existing grants dedicated to this task.

Consider using the data as a basis for reducing the costs of electric vehicle ownership by quantifying the monetary benefits of second-life batteries.
Based on favorable data from pilot projects, the California Public Utilities Commission should consider allowing electric vehicle automakers or customers to monetize the residual second-life battery value upfront to reduce purchase costs or monthly charging costs.

Automotive, Battery & Other Industry Leaders

Work with agencies to improve the quality and market relevance of second-life battery demonstration projects.
Agency and industry leaders should collaborate to develop more market-ready pilot

projects, including through incentives for business participation.

Convene experts to inventory, monitor and address the most pressing federal and state regulations that affect second-life battery deployment.
Perhaps in coordination with a federal- or state-led effort discussed above, the affected industries should gather experts on regulatory policy to assess the current regulations, regulatory gaps, and projected future of regulation, as well as ongoing regulatory needs given various possible ownership models over multiple stages of use.

Identify and replicate through new policy existing liability models for automotive parts for application to second-life battery liability.
Numerous automotive parts are reused, refurbished, and repurposed for subsequent owners, sometimes in ways the original manufacturer never intended, yet the manufacturer is protected in many cases by liability shields that could be applied to second-life batteries.

Develop technical performance standards for second-life batteries.
Industry groups can voluntarily develop safety and performance standards for second-life electric vehicle batteries to help address liability concerns.

Enlist the insurance market for assistance in developing liability coverage for the second-life battery market.
Insurance companies could provide coverage for businesses that want to enter the second-life battery market and could help fund neutral studies on risks and standards development.

Identify the type of "first life" battery data that is most useful for making second-life market decisions, based on classifications and the most promising applications.
Industry leaders, with public sector support, may need to engage in a broader effort to track and collect data on battery performance.

Make available battery register data from first life uses.
Second life batteries can only function well if the new owner understands the condition of the batteries from the first life usage.

Table 1: Types of plug-in electric vehicles available to consumers[1]

Battery Electric Vehicles (BEV)
Battery Electric Vehicles, also called BEVs, are fully-electric vehicles with rechargeable batteries and no gasoline engine. The Nissan LEAF, BMW i3, Mitsubishi I MiEV, Ford Focus Electric, and Tesla Model S are examples.

Plug-in Hybrid Electric Vehicle (PHEV)
Plug-in hybrid electric vehicles (PHEVs), which are powered by both an electric motor that uses energy stored in a battery and an internal combustion engine (or other propulsion source) that runs on fuel, such as gasoline or diesel. The battery is charged by plugging the vehicle into an electric power source. PHEVs can have either a parallel configuration, where both the electric motor and the engine can drive the wheels directly, or a series configuration, where the engine is used to generate electricity for the electric motor and only the motor can drive the wheels. While "standard" hybrids can (at low speed) go about 1-2 miles before the gasoline engine turns on, PHEV models can go anywhere from 10-40 miles before their gas engines turn on. The Toyota Prius Plug-in and Ford Fusion Energi are examples of PHEVs. The Chevrolet Volt and Cadillac ELR are examples of extended range electric vehicles (EREVs), another type of PHEV.

The Value of Second-Life Batteries

What is a Second-Life Electric Vehicle Battery?

Chemical batteries in electric vehicles provide a fast and large power supply. Most current plug-in electric vehicles – defined as vehicles that plug into the grid for some or all of their power – use lithium-ion batteries (see Figure 1). These batteries, albeit in different formats, are also commonly used in most portable consumer electronics, such as cell phones and laptops, due to their high energy per unit mass relative to other electrical energy storage systems. However, the exact chemistry of vehicle batteries often differs from consumer electronics batteries, as well as from each other depending on the automaker. Batteries in vehicles overall have a higher total power capacity and size.

Automakers prefer lithium-ion batteries because they deliver superior performance in both power and energy density, allowing them to achieve a high weight-to-performance ratio. In addition, most components of lithium-ion batteries can be recycled.[2] Participants at the convening noted that increased manufacturing and economies of scale has reduced costs and extended their useful life cycle, with projected price decreases of approximately seven-to-eight percent per year.[3]

The life-span of batteries in the vehicles depends on chemistry and use. Batteries are susceptible to time and age, and the precise capacity will vary depending on a number of variables including battery design, temperature, charge protocol, and the state of charge

Figure 1. Three of the More Widespread Electric Vehicle Battery Packs in Use
Source: California Center for Sustainable Energy

operating window.[4] The batteries will typically decrease to about eighty percent of the original capacity after ten years, depending upon the aforementioned factors.[5] At the end of the vehicle life, the battery pack will be removed from the vehicle and available for secondary use applications or recycling. Some electric vehicle drivers may want to replace degraded batteries with new ones in order to restore the vehicle's original all-electric driving range. While a battery with 60-80 percent capacity will significantly limit driving range, it will still retain enough capacity for use in other applications.

Delaying Recycling Through Repurposing

Recycling lithium ion batteries entails costs and potential waste, making their repurposing for a second and even third life even more important in order to maximize their economic and environmental value before recycling. Three types of processes are currently available for recycling electric vehicle batteries. First, the batteries can undergo a smelting process, available on a large scale for various types of batteries, including lithium ion and nickel metal hybride batteries. These batteries are fed into the smelter to recover valuable metals. Remaining materials such as lithium are lost to slag but may be used for the production of concrete.[6] Second, direct recovery processes, not available for all types of battery, involve separating components through various physical and chemical processes, including hydrometallurgical technologies,[7] and then recovering any battery-grade materials directly.[8] Finally, intermediate processes, which involve extracting solely dangerous battery components at the end of the battery life,[9] help minimize the amount of hazardous substances that make their way into the environment.[10]

> "The costs of alternatives are high. Recycling is really expensive, and disposal and transportation logistics are very expensive. These batteries are big and heavy assets with a hazardous waste designation."
>
> *-- Dirk Spiers*
> *ATC New Technologies*

To date, no facility exists in the United States for lithium battery recycling, although Retriev Technologies (formerly Toxco) plans to begin this operation at its recycling plant in Ohio. The plant currently processes lead acid and nickel metal hybride batteries used in the current generation of hybrid electric vehicles. Pursuant to a $9.5 million grant from the U.S. Department of Energy, it will soon expand to allow for the processing of more advanced (large-format) lithium ion batteries from electric vehicles. The process will involve separating the battery components and recycling the materials to recover battery-ready materials, including nickel, cobalt, copper, lithium and other metals from cell and module enclosures.[11]

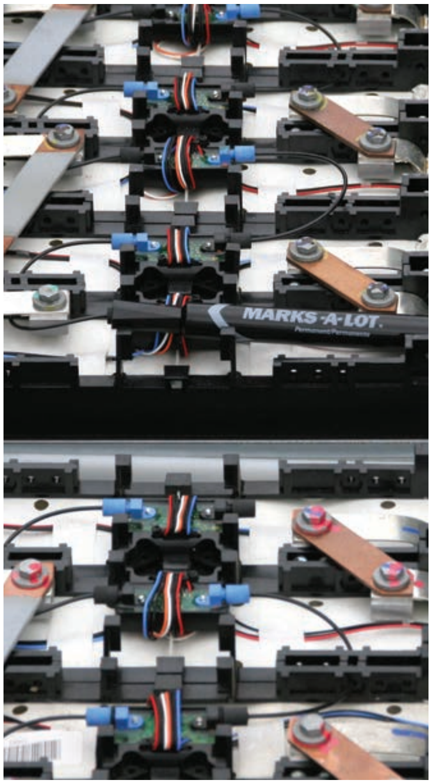
Recycling batteries adds costs to the overall lithium ion battery technology.[12] In addition, few overarching U.S. laws and regulations govern battery recycling. The Mercury-Containing and Rechargeable Battery Management Act of 1996 sets forth requirements regarding the disposal of batteries from plug-in electric vehicles, but its scope is limited and excludes lithium ion batteries.[13] Second, the Electric Vehicle Deployment Act of 2010 merely directs the Secretary of Energy to carry out a study on recycling materials from electric vehicle batteries.[14] As a result of the costs and uncertainties, policy makers should ensure that recycling only occurs once the entire useful life of the battery has been exhausted for various applications.

The Potential Economic and Environmental Benefits of Second-Life Batteries

Instead of recycling them immediately, the thousands of batteries that will be coming out of electric vehicles in the coming years could be repurposed, leading to a flood of inexpensive batteries that can provide energy storage services for customers, utilities, and grid operators. Researchers from the California Center for Sustainable Energy estimate that the potential second-life battery supply already in existence could total 850 megawatt hours of electricity, at 425 megawatts worth of power, assuming 50 percent of the battery packs in use as of 2014 can be repurposed with 75 percent of their nameplate capacity.[15] These second-life batteries could provide multiple value streams to customers and grid operators and benefit the environment by integrating variable renewable energy and reducing the upfront cost of electric vehicles.

Because second-life batteries will retain significant capacity, they may be well-suited for various customer and grid applications, particularly if aggregated for bulk energy storage.

Residential and commercial customers may also use them in combination with on-site solar power for backup supply. For example, some analysts estimate that batteries from lower-range electric vehicles, such as the Chevy Volt and Cadillac ELR, could provide half a day worth of household electricity usage, while batteries from higher-range electric vehicles, such as the Mercedes SLS and the Tesla Model S, could provide a few days of household electricity usage.[16] However, some analysts caution that third parties are unlikely to be able to repurpose the entire electric vehicle battery without first breaking them down to the cell level, matching the cells to other "like" cells, reconfiguring them via new packaging, adding new battery management systems and then deploying and servicing them with a warranty. This process will involve extra cost and complexity.



Inexpensive Second-Life Battery Energy Storage Can Help Integrate Variable Renewable Energy

Utilities could purchase second-life batteries for a wide variety of applications, including reducing the need for new distribution and transmission investments, providing ancillary services, and shaving peak loads. But most significantly, these batteries could help integrate variable renewable energy, when the sun does not shine and the wind does not blow. Grid operators have a number of options to balance the grid without producing more greenhouse gases, such as utilizing dynamic demand management and developing a more interconnected, western-regional grid with an energy imbalance market that can ship renewable power from overproducing areas to under-producing ones across the continent. Yet only large-scale energy storage has the advantage of using renewable energy more efficiently and providing additional grid services.[17]

The greenhouse gas benefits of integrating variable renewable energy with energy storage are significant and critical to California and the world. Without this deployment, the state would not be able to meet its goals under the California Global Warming Solutions Act of 2006 (AB 32) to roll back greenhouse gas emissions to 1990 levels by the year 2020 (equivalent to a 15 percent cutback from the business-as-usual scenario projected for 2020).[18] Former California Governor Arnold Schwarzenegger's Executive

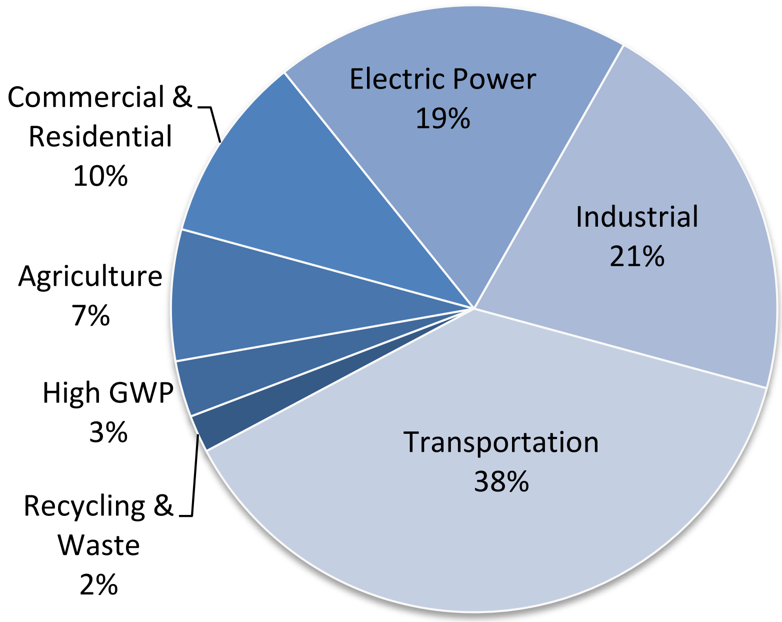


Figure 2. Statewide GHG Emissions by Sector (2011)

Source: California Air Resources Board

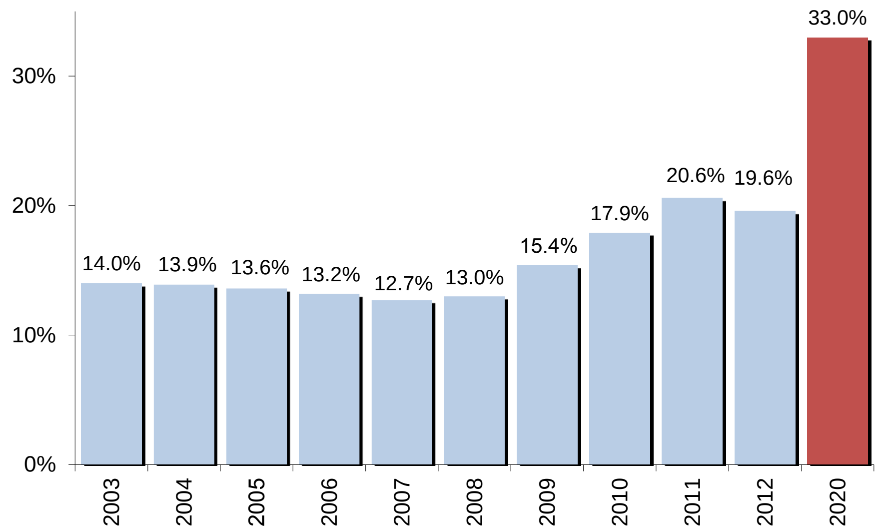


Figure 3. California's RPS Progress

Source: California Public Utilities Commission

Order S-3-05 additionally calls for an eighty percent reduction from 1990 levels by 2050.[19] Because the state's electricity sector is one of the largest sources of statewide greenhouse gas emissions (contributing roughly 21 percent in 2012, see Figure 2),[20] the state's climate change goals necessitate reductions from this sector. The most promising approach is to switch from fossil fuel-based energy to integrated renewable sources, with energy storage serving as one of the critical technologies to help the integration process.

California is making significant progress requiring and deploying renewable energy, making energy storage even more critical. After a decade of renewable portfolio standards in effect,[21] Governor Jerry Brown significantly expanded the program in 2011 by signing Senate Bill X1-2 (Simitian), which increased the renewables target to 33 percent by December 31, 2020 for all utilities.[22] In 2013, the governor signed AB 327 (Perea), which authorizes the California Public Utilities Commission to increase the renewable procurement beyond the 33 percent ceiling and its interim targets, if necessary.[23] Ultimately, achieving the 2050 greenhouse gas reduction goal will require a significant overhaul of the state's energy systems to low- and no-carbon electricity generation,[24] most prominently (and feasibly) from renewable energy.

California is on course to meet both its intermediate and 2020 renewables targets (see Figure 3), but the increased variable generation will soon strain the grid, raise customer rates, and possibly set back the greenhouse gas reduction goals without more energy storage technologies like batteries in the coming decades.[25] Between 2003 and 2013, the state's utilities deployed 7,267 megawatts of new renewable generation in commercial operation, including 2,769 megawatts in 2013 alone. The California Public Utilities Commission forecasted that the renewable portfolio standards program would generate 2,721 megawatts of new renewable capacity in 2014.[26]

Second-Life Batteries Can Boost Energy Storage Deployment Overall

With the state now well on its way to meeting the renewable targets, aggregated second-life batteries may be well-positioned to help integrate this variable renewable energy while minimizing greenhouse gas emissions. Recognizing the integration challenges associated with the renewable energy surge, as well as the need for low-carbon solutions for various customer and grid needs, California has taken steps to bolster the energy storage market. On September 29, 2010, California enacted AB 2514 (Skinner), the nation's first state law calling for grid-scale energy storage. AB 2514 required the California Public Utilities Commission to determine procurement targets, if any, for "viable and cost-effective" energy storage systems to be achieved by 2015 and 2020 for investor-owned utilities and by 2016 and 2021 for publicly owned utilities.[27] On October 17, 2013, the California Public Utilities Commission approved decision D.13-10-040 adopting mandatory energy storage procurement targets for California's three largest investor-owned utilities of 1,325 megawatts by 2020, as well as for the state's retail electric service providers and community choice aggregators (see Figure 4).[28]

The investor-owned utilities can choose from a variety of energy storage technologies,[29] including batteries, thermal storage, flywheels and compressed air.[30] The inclusion of

Storage Grid Domain (Point of Interconnection)	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	**90**	**120**	**160**	**210**	**580**
Pacific Gas and Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	**90**	**120**	**160**	**210**	**580**
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	**20**	**30**	**45**	**70**	**165**
Total - all 3 utilities	**200**	**270**	**365**	**490**	**1,325**

Figure 4. California's Energy Storage Procurement Targets

Source: California Public Utilities Commission

battery storage technologies, however, such as early deployment technologies like lithium-based batteries, could lead to significant adoption, given their relatively small size, modularity and rapidly declining costs.[31]

With the AB 2514 energy storage mandate, electric utilities are now shopping for technologies like batteries, presenting a potentially significant market for second-life batteries. Used electric vehicle batteries qualify for each of the three categories of the energy storage mandate and may represent a more dependable type of energy storage than other untested technologies, given that they have been previously owned and refurbished by a third party, compared to new energy storage technologies. Utilities may also therefore be able to procure them for less than new energy storage systems.

The investor-owned utilities filed their energy storage procurement applications on February 28, 2014, including for two sodium-sulfur batteries at a combined capacity of six megawatts,[32] an eight megawatt lithium ion battery storage project, and the Los Angeles Air Force Base vehicle-to-grid project.[33] San Diego Gas & Electric reported eligible projects 50 megawatts in excess of requirements, including a microgrid project that integrates a 500 kW/1500 kWh lithium ion battery system and three 25 kW/50 kWhr lithium polymer batteries.[34] These purchases represent just the beginning of an expanding market for energy storage, of which second-life batteries could play a substantial part.

Existing Federal and State Programs to Boost Energy Storage

A number of federal and state initiatives to promote energy storage complement this state-level energy storage activity (see Figure 5) and could benefit second-life battery deployment. At the federal level, the U.S. Department of Energy launched a significant energy storage program in 2009 pursuant to the American Recovery and Reinvestment Act, offering $185 million in federal funds to match $772 million of energy storage projects.[35] As of December

Photo of University of California San Diego (UCSD) second-life EV battery project facility

2013, an estimated total of 59 megawatts of energy storage capacity was expected to have come online by 2013, accounting for 7 of the 16 American Recovery and Reinvestment Act-funded projects.[36] In addition, a recent U.S. Internal Revenue Service ruling confirmed that batteries used to store solar electricity may qualify for the 30 percent energy investment tax credit that renewable systems can access, provided, however, that in order to avoid tax recapture, 80 percent of energy discharged by the energy storage technology must have been produced by the solar system.[37]

At the state level, California leaders expanded the Self-Generation Incentive Program to include rebates for the installation of advanced energy storage systems by customers, leading to increased demand for backup on-site batteries for homes and businesses.[38] The unexpected shutdown of Southern California's lone nuclear power plant in 2013 led to the California Public Utilities Commission requiring Southern California Edison to procure 50 megawatts of energy storage capacity for the Los Angeles basin by 2020.[39] And California required its investor-owned utilities on May 13, 2013 to implement a standardized Permanent Load Shifting Program. Under this $32 million incentive program, customers will receive $875 per kilowatt shifted from the peak electric period – up to a maximum of $1.5 million per project – for energy storage systems that "permanently" move a building's demand from hot afternoon peak times to other times.[40] These programs are in addition to the energy storage mandate under AB 2514 and could, with some reform, stimulate the deployment of second-life batteries.[41]

Energy storage pilot projects

In response to the growing private and public sector support for energy storage technologies like second-life batteries, more companies and research agencies are developing and supporting pilot projects to test energy storage in the marketplace. The California Energy Commission and the California Public Utilities Commission have both supported energy storage pilot projects to meet the 1,325 megawatt target. Among the current initiatives, the California Energy Commission issued in April 2014 a request for energy storage projects with grant awards up to $6 million.[42] The agency previously issued grants for projects like

Figure 5. Federal and State Energy Storage Programs

Federal

- U.S. Department of Energy administered $185 million in American Recovery and Reinvestment Act funds to match $772 million of energy storage projects.
- U.S. Internal Revenue Service ruling allows batteries used to store solar electricity to qualify for the 30 percent energy investment tax credit that renewable systems can access, provided that 80 percent of energy discharged by the energy storage technology is produced by the renewable system.

California

- California Public Utilities Commission requires energy storage procurement targets for California's three largest investor-owned utilities of 1,325 megawatts by 2020, as well as for the state's retail electric service providers and community choice aggregators.
- Southern California Edison must procure additional 50 megawatts of energy storage capacity for the Los Angeles basin by 2020.
- Self-Generation Incentive Program includes rebates for the installation of advanced energy storage systems by customers.
- Permanent Load Shifting Program provides $32 million in incentives for customers to shift peak demand through energy storage systems that "permanently" move a building's demand from afternoon peak times to other times.

the $3.3 million Yerba Buena Battery Project (a four megawatt sodium-sulfur battery storage system located in the Silicon Valley),[43] a one million dollar grant to support the Tehachapi Project,[44] an eight megawatt lithium ion battery storage project in Southern California, and $500,000 to support EnerVault's Turlock project,[45] the first grid-scale iron-chromium redox flow battery deployed in the world.

Private companies have also initiated pilot battery storage programs. For example, Sumitomo Corporation and Nissan have begun experimenting with used batteries to develop a commercial-scale energy storage system, while General Motors is using second-life batteries to develop a microgrid backup system.[46] Pacific Gas & Electric also began a pilot program to study plug-in electric vehicle batteries as demand response resources.[47] These pilots indicate growing investment and experimentation with energy storage systems, indicating the beginnings of new market opportunities that could benefit second-life batteries.

Second-Life Battery Sales Could Lower Electric Vehicle Costs to Benefit California's Environment and Economy

The expanding residual market for second-life batteries could provide an upfront economic benefit to electric vehicle owners. Manufacturers or vehicle purchasers can factor in the residual value of the battery in the upfront cost. At the low estimated end, a 2012 study by the Society of Automotive Engineers (SAE) International found that a vehicle owner could conservatively expect to receive $20-$100 per kilowatt hour as a sale price on a used battery. The study authors noted that potential competition from cheaper new batteries in the future would drive down the resale value. Factoring in the cost of repurposing the automotive battery after purchase from the vehicle owner, the authors forecasted that end users would pay a sales price of approximately $38 per kilowatt hour to $132 for repurposed second-life batteries.[48] However, these estimates may not include the full range of applications and market opportunities that could be available pursuant to more aggressive energy storage policies and improved tariffs for the grid services provided by these batteries.

"In 30 years we went from several hundred electric vehicles on the road to 80,000 plug-in electric vehicles today, with 2.25 gigawatts of storage capacity in lithium ion alone."

-- Mike Ferry
California Center for Sustainable Energy

A reduction in electric vehicle prices by factoring in battery resale values could boost deployment by making the vehicles more affordable and competitive with non-plug-in models. For example, based on the SAE estimates described above, a used 24 kilowatt hour Nissan LEAF battery could net the vehicle owner up to $2,400 in resale value, while a Tesla Model S owner could sell the 85 kilowatt hour battery pack for up to $8,500. This future revenue could lower upfront prices or encourage vehicle purchase decisions, leading to greater electric vehicle adoption.

Higher electric vehicle adoption rates would dramatically improve California's economy and environment. The vehicles reduce air pollution, saving lives and significant health care costs. In addition, the state's transportation sector accounted for over 37 percent of the 2012 greenhouse gas emissions that cause climate change, making it the single largest source, compared to 33 percent nationwide (see Figure 2).[49] Electric vehicles also save California drivers fuel costs with the cheaper price of electricity per mile compared to gasoline per mile (between one-half to one-quarter the price) and reduced maintenance costs. Finally, electric vehicle purchases benefit the domestic economy through the growth of new California-based electric vehicle automakers and component suppliers and by ensuring that fuel for the vehicles (in the form of electricity) comes from local sources.

Electric vehicle deployment also promises to help California achieve its renewable energy generation goals. Electric vehicle purchases stimulate further research and breakthroughs in battery technology, which benefit grid-scale battery deployment. More plugged-in electric vehicles, charging on the grid simultaneously, could help integrate renewable energy. A 2010 report from the ISO/RTO Council found that if plugged in simultaneously, the estimated one million electric vehicles expected to be deployed over the next decade could have staggered car-charging times by eight- or twelve-hour periods. This staggered charging would in turn enable grid operators to use the batteries as distributed and aggregated energy storage devices. Grid operators could then use these assets for grid services and therefore use electric vehicles to improve reliability.[50]

The Potential High Volume of Second-Life Electric Vehicle Batteries

As electric vehicle purchases increase, the number of batteries that will become available for a second life outside of the vehicle increases. The number of all-battery electric vehicles in the United States has grown steadily, particularly in California, which represents one of the biggest auto markets in the world (see Figure 6). Los Angeles and San Francisco alone represent two of the largest markets in the U.S., accounting for 35 percent of total plug-in electric-vehicle sales in the country. And because California's air quality policies have resulted in zero-emission vehicle targets, automakers plan to sell zero emissions vehicles up to 15.4 percent of new-vehicle sales by 2025. As mentioned previously, second-life batteries on the road as of March 2014 could already provide 850 megawatt hours of energy storage. That second-life energy storage potential could increase fifteen-fold by 2025 if California successfully meets its goal of having 1.5 million electric vehicles on the road by that year.[51]

California has implemented policies to enhance the market for electric vehicles, which will eventually lead to an even greater supply of second-life batteries. California's Zero Emission Vehicle program provides a marketplace for credits earned from the sale of electric and other low-emission vehicles. Companies that fail to comply face fines and potential restrictions on sales in California.[53] The 2014 California state budget also dedicated $200 million in auction revenue from the state's greenhouse gas trading program (allocated at $832 million in the first year) to low carbon transportation construction. A portion of the revenue will boost funding for the California Air Resources Board's Clean Vehicle Rebate Project, which provides rebates up to $2,500 for the purchase of a zero-emission or plug-in hybrid electric vehicles by individuals, nonprofit groups, government entities and business owners.[54] All told, these policies promise that California will remain among state leaders in electric vehicle adoption rates and therefore in supplying second-life batteries.

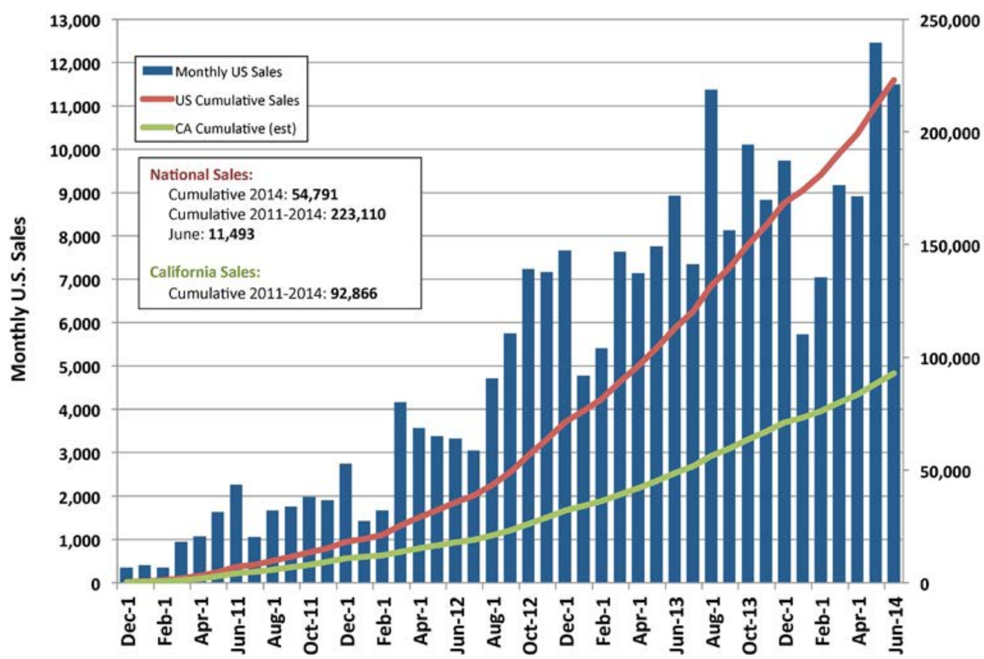


Figure 6. Electric Car Sales: CA vs. National

Source: California Plug-In Electric Vehicle Collaborative

Barrier #1: Economic Uncertainty About Second-Life Battery Value Translating to Reduced Upfront Vehicle Costs

Participants described four primary factors that may limit the economic viability of a second-life battery market:

1. **Uncertain economic return and market for many energy storage applications.** The uncertain market includes many of the applications most suited for second-life batteries, such as backup power and aggregated, bulk energy storage. Utilities and other potential customers have not yet optimized these applications. Further complicating matters, different energy storage technologies fit different market segments, many of which have financial benefits that are not yet monetized in the highly regulated world of electric utilities.

2. **Potential future competition from cheap new energy storage.** Second life batteries must compete with future energy storage technologies on price, in whatever application they might fit. While industry leaders expect second-life batteries will be cheaper than other forms of energy storage, particularly other batteries, second-life batteries will have to compete with less-expensive versions of current lithium ion batteries, plus other chemistries like flow batteries. Industry leaders therefore face difficulty gauging the long-term cost curve without knowing the price of the likely competition, especially given the uncertainty around how well the second-life batteries will perform out of the vehicles.

"We're competing with the decreasing cost of first life batteries, as well as the time scale."

-- Gopal Garg
SunPower

3. **Potentially expensive repurposing or redesigning of the battery pack for new applications.** Second-life batteries may be best suited for some grid and customer applications that require significant and expensive re-designs of the battery during the repurposing stage. In some cases, new owners could simply reuse the battery packs, representing the most ideal and efficient way to repurpose them. However, some parts of the battery could be more lucrative than others, requiring businesses to incur costs to dismantle, certify and prepare them for new applications. The original battery owners will also need to transfer responsibility for recycling them, as well as any liability costs. Some participants noted that the cost of processing the battery is currently $50 per kilowatt hour. In order for second-life markets to thrive, the cost of the battery, plus this processing fee, must be lower than the expected revenue to attract financial backing and encourage deployment.

"Application drives standardization. Think about AA batteries: replacement necessities were really common, so that drove standardization, whereas battery packs in power tools are not standardized because you don't change batteries all that much."

-- Pablo Valencia
General Motors

4. **High repurposing costs may limit opportunities for financing**. The second-life battery market will need access to financing to become widespread. By way of analogy, many consumers finance the purchase of a new car but pay cash for used cars. In this case, financing second-life batteries will enable greater deployment. However, second-life battery customers may experience difficulty securing this financing to repurpose the battery for a new use.

Solution: Reduce uncertainty and costs in the second-life battery market through demonstration projects and financial and regulatory support

Federal and state leaders should encourage more demonstration projects by improving grant support and reducing administrative barriers to implementation.

Demonstration projects help assess the costs and benefits of second-life battery applications and can encourage more private investment if successful. Businesses are otherwise reluctant to invest without some assurance regarding the potential risks and rewards. While public agencies currently fund some demonstration projects through grants, many participants felt that the grant application forms were too cumbersome, feedback and decisions from granting agencies too delayed, and reporting and accounting requirements too strict to encourage a sufficient and diverse array of projects. They also wanted more clarity about which business entities involved would own whatever intellectual property they created. They noted that California agencies have simplified the process somewhat, along with the federal Advanced Research Projects Agency-Energy (ARPA-E) agency that funds many cutting-edge clean technology projects. However, participants believed that the agencies could accomplish more streamlining.

"Make it simple to do demonstrations."

-- Workshop Participant

Failure to improve the grant process could hamper California's ability to gather the best information from the right companies. Participants observed that large companies often have their own resources to pursue demonstration projects, which leads them to ignore small grants, while potentially more innovative smaller companies that need grants often lack the resources to apply for them and administer the grants once received.

As a starting point, participants recommended that agencies develop grant programs that reduce the overhead costs required to comply with grant processing needs. They cited a situation where a small project perhaps unintentionally required a 25 percent overhead fee in order to meet the grant guidelines, making the project financially infeasible to pursue for the company involved.

"The CIA is great for supporting projects – they pay right away, and they have very few hooks."

-- Workshop Participant

State and industry leaders should improve the quality and market relevance of second-life battery demonstration projects.

Participants felt that current solicitations for demonstration projects did not reflect the best business cases or most appropriate business entities that could be involved. They recommended that state and industry leaders conceptualize the "perfect research and development project" as a starting point. For example, separate automakers could join forces to prove through research that the batteries can be aggregated in isolation. The automakers could also collaborate on a project proposal description for agencies to consider funding, rather than attempting to fit a project into existing grant opportunities like for the Electric Program Investment Charge (EPIC) program at the California Public Utilities Commission. Participants believed that the EPIC program in particular does not currently encourage collaborative research and development (of note, EPIC seeks to fund at least one second-life battery research project for distributed energy storage[55]). They also noted that the California Energy Commission may want project proponents to collaborate with utilities, which may not be optimal in all cases.

Overall, participants felt that projects that represent near-term monetizable ideas were more likely to attract top-flight private companies that would be more likely to share costs and dedicate top personnel. Participants wanted projects funded that develop a business case around a specific second-life implementation with a projected cost model. As a tradeoff for the increased flexibility, public agencies could then encourage private partners to share a greater percentage of the costs. With additional profit incentives attached to the projects, automakers and other parties may be willing to provide more match-based funding.

Federal and state leaders should remove regulatory barriers to allow second-life battery pilot projects access to specific grid markets.

Participants wanted agencies to help give pilot projects access to the market via regulatory pilot project exemptions and exceptions. For example, demonstration projects may need approval to bid for services with the California Independent System Operator (CAISO), which in turn may need to simplify the access process to let project proponents prove the functionality of the technologies. Policy makers may also need to allow interested parties the ability to test demonstration project arrays by sending signals, offering diverse geographical access and testing, trying them through remote access, and letting participating utilities have a definite time frame, such as a month each, to control the asset. The demonstration participants would need system access without charge, provided the applications involve large-scale projects. In addition, entities like the CAISO might consider committing to new tariff structures based on any discovered value of second-life battery applications that project proponents can demonstrate.

Without these regulatory exemptions for pilot programs, current interconnection processes can take years. Grid operators like the CAISO impose various rules and procedures for connecting energy facilities to the grid system, which present significant barriers for energy storage technologies such as second-life battery pilot projects. First, projects must be placed in the interconnection queue, which must be submitted during the appropriate cluster application window between April 1 and April 30. Second, interconnection studies must be performed for each project. The interconnection study process generally begins in late July and takes two years or more to complete, though a fast-track process may be available in some cases. Following this effort, the project proponents may submit a completed interconnection request consisting of the interconnection study deposit, the completed application form, a demonstration of site exclusivity or a site exclusivity deposit, and the requested deliverability status (full, partial, or energy only). Third, the resource must be modeled in the CAISO's market systems and metering, and telemetry equipment must be installed. These additional steps take six months or more to complete. Although the CAISO recently initiated a process to obtain broad stakeholder input to improve the process, demonstration projects will otherwise be unable to interconnect quickly for the foreseeable future. [56]

"Mitsubishi already has a battery reuse project as part of a smart city program in Japan. The reason why we have it is because the government asked us to do so. We would do a demo project in California if state leaders came to us. And this is done on a large cost-share basis, so it's not just government funded."

-- David Patterson
Mitsubishi

Federal and state leaders should offer tax credits, rebates, and other financing support for second-life demonstration efforts.

Public sector financial support, at least to cover part of the project costs, can make the difference in getting a demonstration launched. Participants noted that the U.S. Department of Energy prefers tax credits and rebates as an efficient method of encouraging research and development. Government grants may be less effective in comparison but may still have an important role.

Given the uncertainties associated with second-life batteries, participants also recommended that the government pledge to absorb the risk of any low-quality assets discovered in the process of providing grid services or reducing greenhouse gas emissions. The government could guarantee a base level of performance for batteries used in certain promising applications, such as when the battery pack does not need a redesign. The government could create simple criteria for private entities to obtain this support.

Federal leaders should assign liability for second-life batteries to avoid stifling innovation and experimentation.

The government, with industry support, should clarify and remove liability for faulty second-life battery products in instances of third party reuse (see discussion below).

Barrier #2: Complex and Potentially Adverse Regulatory Environment

Second-life battery usage involves the complicated worlds of utilities, hazardous and toxic wastes, and local permitting, among others. Regulations involving electric utilities represent some of the most complex of any industry, and many promising second-life applications require entering this market. Indeed, energy storage technologies in general face multi-faceted public utilities commission proceedings given their diverse applications, technologies, and potential revenue streams. In addition to these regulatory hurdles common to energy storage, participants cited additional challenges, such as regulations regarding the transportation of used electric vehicle batteries (currently classified as hazardous waste) and disposal and recycling. In addition, some incentive programs meant to benefit energy storage generally have the unintended effect of discouraging second-use batteries by not including used assets as eligible for incentives. Finally, at the customer end, state and local permitting authorities may object to siting second-life batteries based on uncertainty regarding fire safety and other feared environmental impacts of these new uses. Overall, the multiple regulatory hurdles, at overlapping jurisdictions, make for a daunting process that can dampen private sector willingness to invest in the second-life potential.

"The footprints of these battery technologies are important. These systems will be larger and we have limited space in congested subsystems."

-- Armando Infanzon
San Diego Gas & Electric

Solution: Inventory, map, and address the suite of regulations affecting second-life battery deployment

Federal and state policymakers should consider committing to develop clear and consistent regulations over specified time lines.

As a long-term goal, policy makers should consider developing clear regulations on second-life batteries that businesses can rely on for an extended period of time. As a preferred time horizon, participants felt that the five- or ten-year period following 2018 would be helpful to avoid changing the basic rules governing second-life batteries if possible. In addition, policy makers could help the market grow by coordinating the different regulations and timelines at multiple agencies affecting second-life batteries in order to ensure consistency and predictability for investment.

State policy makers, such as the California Energy Commission, or industry leaders should fund an expert panel to inventory, monitor, and address the most pressing agency regulations that affect second-life battery deployment.

Participants recommended that either the California Energy Commission or affected industries gather experts on regulatory policy to assess the current regulations, regulatory gaps, and projected future of regulation, as well as the regulatory needs, based on different models of asset ownership at various stages of use. They suggested a regular meeting schedule to ensure common alignment. Some thought the National Alliance for Advanced Technology Batteries (NAATBatt) could be a logical convener, including the automakers and other participants in the energy storage market, such as the solar industry. Their goal would be to "harmonize" regulations, perhaps with a California focus, given the strong electric vehicle and energy storage market in the state that could lead other states and the nation. Other groups to consider could include the California Electric Transportation Coalition (CalETC) and the California Plug-In Electric Vehicle Collaborative (PEV Collaborative).

Participants recommended that the regulatory group produce a document that lays out all the regulatory issues and delineates various jurisdictional boundaries or standards. The document will provide the industry with clear direction about where the most important regulatory challenges arise and how best they might be addressed to encourage market development while balancing other societal concerns.

Ultimately, participants hoped that a regulatory working group could not only map existing regulations but alert the second-life battery industry to new regulations that could affect market opportunities. For example, one participant noted that California's "green chemistry regulations" from the Department of Toxic Substances Control could affect second life batteries given the wide range of consumer products affected. As a result, second-life battery representatives will want to engage in regulatory debates to make sure their interests are heard.

Regulatory experts could also address and change a range of regulations that may inadvertently and detrimentally discourage a second-life battery market. They noted that regulations governing shipping materials considered hazardous waste may make the transporting of second-life batteries prohibitively expensive for potentially minimal risk. Participants reported accordingly that second-life batteries need to be declassified as "toxic waste" under federal regulations. Regulations regarding the disposal of batteries also place onerous requirements on second-life battery customers and owners, requiring clarification and potentially reconsideration by policy makers. Finally, participants noted that policy makers may need to reduce or remove taxes on lithium in the reuse market that could adversely affect their deployment.

Federal and state leaders should ensure that grid-related incentive programs include second-life batteries as eligible.

California's Self-Generation Incentive Program (SGIP) as well as the federal Investment Tax Credit currently do not include second-life or used batteries. For example, the SGIP rules specifically state that "rebuilt, refurbished or relocated equipment" is ineligible for the incentives.[57] These programs should consider allowing second-life batteries to qualify in order to ensure they face a level playing field of incentives from competing energy storage solutions. Participants also recommended that the eligibility criteria include a performance-based standard, rather than a secondary-life standard.

Federal and state agency leaders should ensure that carbon and grid regulations account for the potential of second-life batteries.

As these leaders develop policies to reduce carbon pollution, integrate renewable energy, and boost energy storage deployment generally, they should consider the multiple benefits that second-life batteries could provide. For example, policies to integrate excessive renewable energy generation should favor second-life batteries to absorb the surplus, and grid operators should change market rules to clarify that these batteries can participate. While participants did not want any particular technologies favored over others, they wanted policy makers to consider the secondary benefits of encouraging electric vehicle deployment in evaluating second-life battery applications and potential.

Barrier #3: Liabilities Uncertainties for Second-Life Batteries

When a battery has a defect or is linked to damages to people or property, the owner is generally liable for some portion, if not all. However, when an electric vehicle manufacturer makes a battery and insures it for use in typical, foreseeable automotive uses, that manufacturer does not necessarily anticipate that the vehicle owner will sell the used battery to another party for uses in creative ways to serve or grid or customer needs. If the second-life uses of the battery result in damages, then the automotive manufacturers that own the original battery may want to discourage or limit secondary uses to avoid liability. Currently, regulations and standards regarding liability for second-life batteries are unclear and may discourage automakers from allowing their batteries to be used outside of the vehicle, other than for recycling.

"The two worlds of SAE and UL need to talk to each other, because at moment there is a clash of standards."

-- Workshop Participant

Solution: Clarify and Improve Liability Standards to Ensure Automaker Participation in the Second-Life Battery Market

Industry leaders should identify and replicate existing liability models for automotive parts for application to second-life battery liability.

Numerous automotive parts are reused, refurbished, and repurposed for subsequent owners, sometimes in ways the original manufacturer never intended. In many cases, the manufacturer is protected through liability shields that limit damages being attributed to them in case of defects or accidents. For example, engines and transmissions typically undergo remanufacturing from older vehicles by dismantler companies. Second-life battery leaders should therefore use liability models from these scenarios to develop a liability structure for second-life electric vehicle batteries.

Industry leaders should develop technical performance standards for second-life batteries.

Industry groups can voluntarily develop safety and performance standards for second-life electric vehicle batteries to help address liability concerns. If codified in statute or regulations, then conceivably any automaker that complies with these standards in selling second-life batteries could be protected from liability for certain damages. Participants recommended that SAE International, a global body of scientists, engineers, and practitioners that advances best practices standards for vehicles, and UL (Underwriters Laboratories), a safety consulting and certification company for electrical technologies like batteries, use their neutral forums to develop safety and liability standards and certification for second-life batteries. Experts from the two organizations could draft them.

Industry leaders should seek policy, such as supportive legislation, to make the performance and safety standards the basis for liability protection.

The industry-drafted safety standards could form the basis for national legislation or regulations to support a second-life battery market. They can help ensure the industry maintains high safety standards and that companies that comply will benefit from increased protection from liability in case of damages.

Industry leaders should enlist the insurance market for assistance in developing liability coverage for the second-life battery market.

Insurance companies could provide coverage for businesses that want to enter the second-life battery market, but they may be concerned about their potential exposure. If insurance companies could help fund studies on the risks as well as the standards development, they might find the market advantageous to enter. The National Fire Protection Association (NFPA), a nonprofit fire safety organization, issued a similar type of report evaluating battery fires in factories. Insurance companies might find that projects benefiting from second-life batteries, such as microgrids, may result in fewer payouts overall from customers who might otherwise lose power or face negative consequences from grid outages and related problems.

Barrier #4: Lack of Data on Battery Life Performance in First and Second Use Applications

With second-life batteries, data on battery performance can spur – or limit – the market. Businesses will determine their financing, engineering, and investment decisions based on promising data. Participants noted a lack of data on second-life batteries due to uncertainty about how the batteries were performing in their "first life" role as mobile energy storage devices. Potential customers for second-life batteries therefore lack knowledge about how the batteries performed in the first instance and under what conditions, as well as how much capacity remains in them. Adding to this uncertainty, industry leaders and investors face a new market with new applications for energy storage more generally, with the batteries used in innovative and sometimes unanticipated ways. In addition, the models that the data feed require anticipating a market a few years from now, with much uncertainty about the cost of – and potential revenue from – energy storage at that time.

Solution: Make Electric Vehicle Battery Data Available

"People are developing business models based on current market circumstances and venture capitalists are taking numbers, but until you do the data acquisition, you don't know what problems are, and you don't know what the actual development and deployment costs will be."

-- Workshop Participant

Industry leaders should identify the type of data that is most useful for making second-life market decisions, based on classifications and promising applications.
A number of companies and research institutions, including universities and national laboratories, are currently testing electric vehicle batteries in second-life applications to assess how well they will perform. Industry leaders, with public sector support, may need to engage in a broader effort to track and collect data on battery performance. They will also need to experiment with different applications, from large utility roles to home- and commercial-scale uses, building data sets on the most promising particular use cases. They will have to acknowledge that data on individual performance of certain technologies will vary based on particularized circumstances and therefore may change performance. Participants preferred that the data be presented by application – probably by state, given California's unique energy storage policies – and would need to be standardized. They warned that the testing data should not be overly based on specific, isolated circumstances and instead should retain the ability to show the value of applications in multiple ways, such as for divergent distribution and transmission grid services.

Automotive leaders should make available battery register data from first life uses.
Second life batteries can only function well if the new owner understands the condition of the batteries from the first life usage. Second-life battery customers will want to see the data on incoming assets and know how the batteries performed and were treated in their first usage. They will then need to know how this history would affect deploying them in their second use. The automakers collect much of the data and could make it accessible. Perhaps they could develop a consumer consent system to protect customer privacy. Consumers may be encouraged to approve based on the potential resale value of the batteries as well as built-in privacy protections.

State leaders should make available utility, government, and grid data to help industry actors understand promising second-life revenue opportunities, via an accessible database with incentives for participation.
Participants recommended that industry leaders focus initially on California Independent

System Operator market participation data in order to find likely revenue streams to attract risk investors. Utilities will likely follow with investment. The utilities will also need to provide data on interconnection, while regulators in government can disclose data related to their electricity and pricing models.

Utilities may be reluctant to release relevant market data on their infrastructure and grid needs out of concerns for ratepayer privacy and a reluctance to empower their perceived competition. The California Public Utilities Commission or Legislature may need to develop mechanisms to encourage utilities to pool data or release it in other ways. Second-life investors will need the data to run simulations to determine business cases. State leaders will need to develop incentives and processes for entities to collect the battery energy data. State leaders should use incentives to encourage otherwise reluctant utilities and automakers to participate in data collection, possibly by starting with a strictly volunteer offering of whatever data and sources might be most easily made available. State leaders can then work collaboratively with these entities to find a method to divulge more data. For example, automakers that are forthcoming with data might receive low-emission credits under the federal CAFÉ program or California's zero emission vehicle system.

"If your facilities people are not in alignment with the researchers, then data collection is going to be difficult."

-- Byron Washom
University of California, San Diego

In addition, the energy data that utilities and grid operators generate will have to be made accessible, transparent and able to be vetted by third parties. A third party website, hosted by an entity like a university or research laboratory, may be optimal to allow market participants to use the data easily and efficiently to create business cases. The data will also need to be standardized. Ultimately, the state should consider developing a California database of energy data related to second-life batteries. Possibly through the California Public Utilities Commission's existing proceeding on energy data, the state should create an independent, third party database of energy data from utilities and government sources. Market participants should be able to access and test the data as needed, while taking into account concerns about customer privacy and cybersecurity. The California Public Utilities Commission should consider allocating funding for this effort in the second phase of the energy data proceeding, including for ongoing data management. The agency issued a briefing paper in 2012 to recommend a similar type of data center.[58]

State leaders should focus on collecting data from second-life battery pilot projects and fund data collection efforts from them.

State leaders should ensure that they receive and collect data from pilot project operators who have control over the full project. Universities and national laboratories are engaging in this research, including for various applications like microgrids, and could make the data available along with their private sector partners. These pilot projects should be feeding information, results, and data back to a central statewide database.

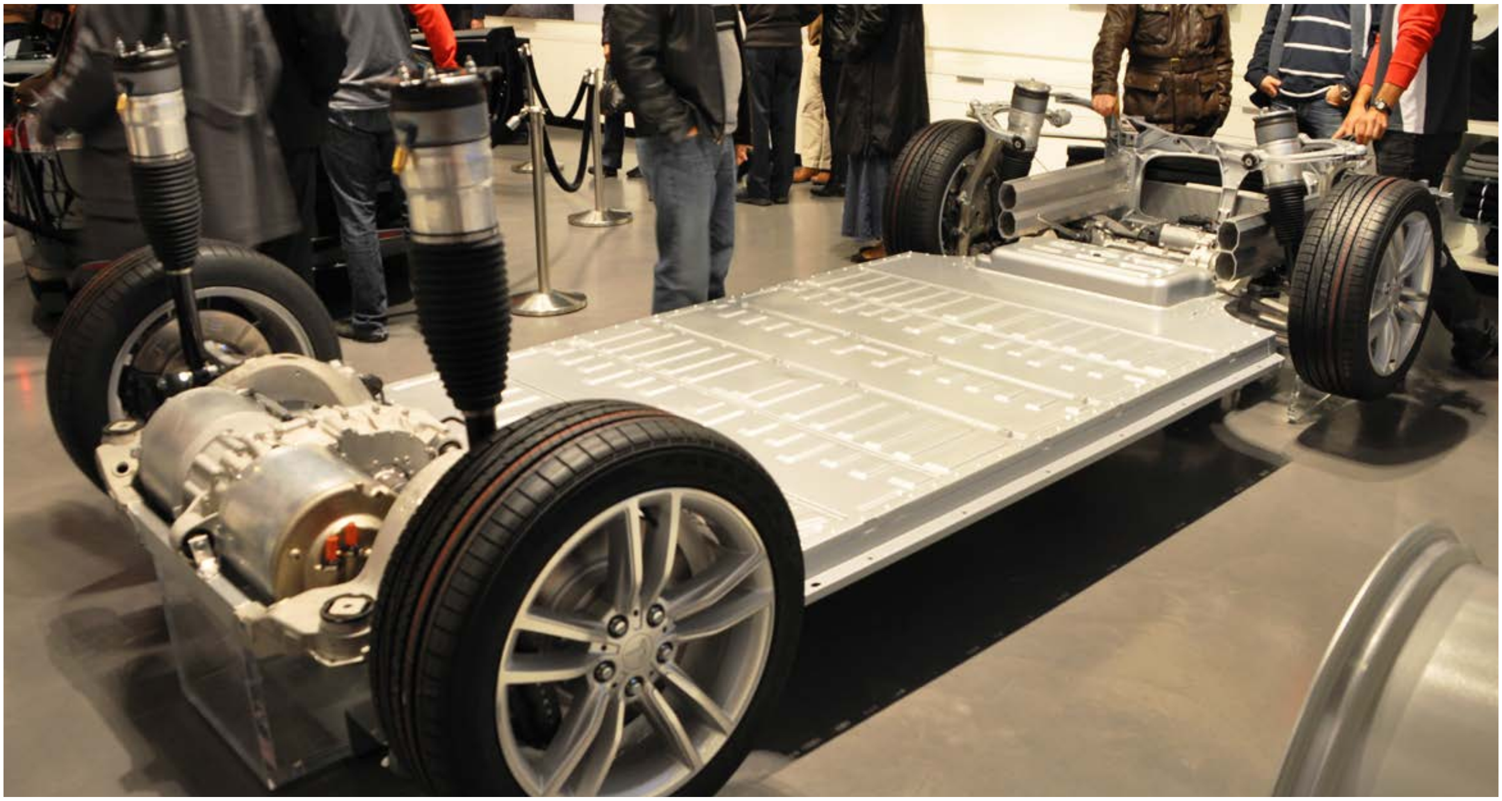
"Transposing residual value from batteries to reduce upfront costs is contingent upon issues like safety, reliability, and creating value to the community."

-- Beth Reid
Olivine, Inc.

To be sure, collecting data and managing the data at the project level costs money. While the state can fund a database to report the information, grantees and other researchers will need funding for this research task. Universities and federal agencies may already have this funding or resources available, but other entities lack funding. Policy makers should therefore consider developing creative funding opportunities, such as requiring utilities to fund some of the data collection as part of their energy storage requirement or through the energy data proceeding at the Public Utilities Commission. The California Energy Commission could also set aside funding for data collection as part of the integrated resource planning for 2016 through 2018. Ultimately, different funding sources may depend on the beneficiaries of different applications. For example, some projects may benefit site owners, transmission grid operators, and electricity providers, while others have environmental or social values. Funding sources should be tuned to applications that meet these needs.

State leaders should consider using data as a basis for reducing electric vehicle ownership costs by quantifying the monetary benefits of second-life batteries.

Based on favorable data from these models and pilot projects, the California Public Utilities Commission should consider allowing electric vehicle automakers or customers to monetize the residual second-life battery value upfront to reduce purchase costs or monthly charging costs. That effort would help turn data into upfront value that could boost electric vehicle deployment.



Conclusion:
The Future of Electric Vehicle Batteries

California is the perfect test bed to launch a second-life battery market. The state is a national leader in both electric vehicle adoption and energy storage procurement. It also leads in renewable energy deployment and greenhouse gas reduction programs, which will necessitate more energy storage to integrate renewables and decarbonize the electricity sector. State leaders can use these policy tools and technologies to harness the significant private capital in the state and beyond to launch a new market for second-life electric vehicle batteries that will bolster both electric vehicles and energy storage. The state could ultimately blaze a trail that other states and countries can follow, providing innovative and economically beneficial uses for second-life electric vehicle batteries.

Glossary of Terms

Battery Electric Vehicles (BEV): Fully-electric vehicles with rechargeable batteries and no gasoline engine.

California Air Resources Board (CARB): An organization within the California Environmental Protection Agency responsible for providing and maintaining clean air, including enforcement of the state's greenhouse gas reduction law.

California Energy Commission (CEC): An agency that reviews requests to build thermal power plants of 50 megawatts or more in capacity, and which otherwise focuses on energy policy and planning for California.

California Global Warming Solutions Act of 2006 (AB 32): California state law which sets out the greenhouse gas emissions reduction goal to be achieved by 2020.

California Public Utilities Commission (CPUC): California's agency in charge of regulating investor-owned utilities.

California Independent Systems Operator (CAISO): An independent, non-profit grid operator responsible for maintaining the reliability and accessibility of California's power grid.

Electric Program Investment Charge (EPIC): California Public Utilities Commission program to provide public interest investments in applied research and development, technology demonstration and deployment, market support and facilitation of clean energy technologies and approaches for the benefit of electricity ratepayers of the three large investor-owned utilities (IOUs).

Energy Imbalance Market (EIM): Automated systems designed to reliably and automatically balance real-time imbalances on the grid that result from deviations in energy supply and demand.

Extended Range Electric Vehicles (EREVs): Vehicles that use a gasoline engine to provide additional range once the all-battery electric drive is depleted.

Investor-Owned Utilities (IOU): A privately-owned electric company that in California is regulated by the CPUC.

Megawatt (MW): A unit of power that is equivalent to one million watts, generally considered as able to provide sufficient power in any given moment to serve approximately 750 households.

Megawatt Hour (MWh): A measurement equal to one million watts of electricity used continuously for one hour, roughly equivalent to the amount of electricity used by about 330 homes during one hour.

Municipal Utility: A political entity, such as a city or county government, that provides utility-related services such as electricity, water, and sewage.

Plug-In Hybrid Electric Vehicle (PHEV): Vehicles powered by both an electric motor that uses energy stored in a battery and an internal combustion engine (or other propulsion source) that runs on fuel, such as gasoline or diesel. The battery is charged by plugging the vehicle into an electric power source.

Renewable Portfolio Standards (RPS): Legal requirements that a specific percentage of retail electrical power for California comes from eligible renewable energy resources.

Self-Generation Incentive Program (SGIP): A state program providing financial incentives to California customers for the installation of eligible on-site energy systems.

Participant Bios

Renata Arsenault
Ford Motor Co.

Renata Arsenault is a Senior Researcher in Ford Motor Co.'s Advanced Energy & Materials Storage Group in Dearborn, Michigan where she has been interfacing closely with battery suppliers since 2006 to ensure quality-focused engineering processes such as FMEA and Design for Robustness are understood and employed proactively in the cell development process. She is a member of the USABC (US Advanced Battery Consortium) Technical Advisory Committee and Program Manager of a $5.5 M USABC PHEV Battery Development program with Johnson Controls Inc. (JCI). She has been actively working on Ford's recycling strategy, liaising regularly with the recycling industry and related forums such as the USABC and SAE on recycling issues. She is involved in numerous facets of Sustainability at Ford, representing the battery group on efforts ranging from Life Cycle Analysis to Strategic Materials. Renata has been a speaker at numerous battery related conferences, including International Congress for Battery Recycling in 2013, 29th International Battery Seminar in 2012 and Advanced Energy Solutions in 2011. Renata spent 1989-1998 working in specialty chemicals for Diversey-Lever where she led process development and scale-up of specialty products in North America. Renata graduated from Queen's University in Ontario, Canada 1988 with Bachelor of Science in Chemical Engineering.

Shouvik Banerjee
SolarCity

Shouvik Banerjee leads business development for SolarCity in the following industry verticals: automotive, consumer marketing, energy efficiency, financial services, and emerging products. Prior to SolarCity, Shouvik served for three years in the Obama Administration, where he worked in the White House and Department of Energy. He also worked on energy and climate projects at McKinsey and Company. Shouvik holds a BS in Computer Science and BA in History from Stanford and an MPP from Harvard.

Paul Beach
SinoEV Technologies

Paul Beach is currently President of SinoEV Technologies (since Aug 2013), which designs, develops and manufactures advanced energy systems for grid storage, electric vehicle drive trains and industrial APUs. Previously, he served as President of Quallion LLC (2009 to Dec 2012), a designer and manufacturer of primary and rechargeable lithium ion custom cells and batteries for use in medical, military, aerospace, HEV/EV/PHEV, and other industries. In this capacity, he raised over $70M in government funding to establish the first US-based, fully vertically integrated Li ion battery factory from cathode and anode materials production through pack design. He also served as Vice President of Business Development for the company (Feb 2001 to Jan 2009), managing marketing and sales, program management and customer support. Prior to joining the Quallion team, Beach was an Associate for Taylor & Co. (1995 to 1999), specializing in representing multinational corporations in complex intellectual property disputes. Beach is proficient in Japanese and holds a B.A. from Colby College, a J.D. from University of Maine Law School, and a L.L.M. from the University of California at Berkeley.

Brian Dillard
Johnson Controls

Brian Dillard was Vice President Engineering at SINOEV Technologies in Silicon Valley between May 2011 and August 2013. SINOEV technologies designs, develops and manufactures Lithium Ion battery systems for automotive and industrial applications in the US and China. Mr. Dillard was previously General Manager for Hybrid Electronics at Johnson Controls from 2010 to 2011 and prior to that Director of Electronics and Product Planning, Battery Management Systems at Johnson Controls where he led the Hybrid Electronics Engineering and business unit. Prior to this, Brian consulted in the Advanced Battery space, clients included Dow-Kokam and their investors, and Magna eCar. Brian was Director of R&D & Electronics at ArvinMeritor, Chief Engineer at Ricardo and had a 14-year career as Senior Manager for Algorithms & Software in TRW Automotive's Braking division. In August 2013 Brian joined a new business unit focused on Stationary Storage at Johnson Controls Power Solutions, where he leads Technology strategy and direction for the business.

Bruce Falls
AVL North America, Inc.

Mr. Falls joined AVL in Oct 2007 as the Director of the AVL California Technology Center. Mr. Falls has 30 years of experience in automotive engineering mostly in powertrain development and vehicle systems integration. He has concentrated on the areas of base engine development, electronic controls, emissions development, alternative fuels applications, and vehicle electrification. Prior to joining AVL he was Director of the Applied Technology Center for Energy Conversion Devices (ECD). Mr. Falls also was the Director of the Advanced Vehicle Concept Center for Quantum Technologies which specialized in prototype and production alternate fuel vehicle programs and hydrogen refueling products to support demonstration fleets. After graduating from the University of Texas

(BSME ’83), Mr. Falls began his career at the General Motors Technology Center located in Warren, Mi. working for Chevrolet Engineering. He was involved in developing advanced emissions control hardware and software control strategies which led to a calibration release engineer position at the Milford Proving Grounds. After four years as a development engineer he joined McLaren USA to work with prototype powertrains and racing applications.

Mike Ferry
California Center for Sustainable Energy (CCSE)

Mike Ferry is Senior Manager of Advanced Energy Projects at the California Center for Sustainable Energy (CCSE) where he oversees a diverse portfolio of initiatives focused on distributed generation, advanced energy storage, smart grid, and electric transportation research and deployment projects. Over the past five years at CCSE, Mike organized and launched the California Air Resources Board (ARB) Clean Vehicle Rebate Project (CVRP) and managed the state’s zero-emission vehicle rebate program as it grew from an annual budget of $4.1 million to a cumulative $120 million over a four-year period. Working with utilities, municipalities, air districts, automakers, and electric vehicle (EV) charging companies, Mike also oversaw regional planning efforts in the San Diego, Los Angeles, San Joaquin Valley, and Central Coast regions supporting the exponential growth in EV adoption and sales. From 2011-2014, Mike served as the Coordinator of the San Diego Regional Clean Cities Coalition, a U.S. Department of Energy (DOE) funded program to promote the use of alternative fuels in the transportation sector. Since March 2011, Mike has led multiple research teams from academia, industry, and government laboratories investigating advanced second-life application for used EV batteries, culminating in two long-term, grid-tied energy storage deployments utilizing repurposed EV battery packs. Mike holds a Master of Science degree from the Energy and Resources Group at the University of California, Berkeley.

Robert (Bob) L. Galyen
Contemporary Amperex Technology Limited

Robert (Bob) Galyen holds the position of President of Global Business Development for Amperex Technology Limited and Chief Technical Officer of Contemporary Amperex Technology Limited, both located in NingDe City, Fujian Province in China. Bob is the Chairman of the SAE International Battery Standards Steering Committee with 20 Committees reporting to him. Also, Bob serves on both the US and China Motor Vehicle Councils for SAE International. He serves on two non-profit organizations including Lugar Center for Renewable Energy Advisory Board at IUPUI and the Dean’s Executive Advisory Council of Ball State University. Bob’s education includes a Master’s degree in Chemistry, with Bachelor’s degrees in Chemistry and Biology from Ball State University. His 37 years’ of work experience in battery technology, manufacturing and business operations has given him a unique perspective on worldwide business. Bob sits on 5 Board of Directors of corporations within the USA. He is the recipient of numerous awards including; the Automotive News “Electrifying 100,” the SAE International Technical Standards Board “Outstanding Contribution Award,” and Ball State University “Circle of Excellence Award.” Most recently Bob received the prestigious “1000 Talent Plan” award from the People’s Republic of China government carrying the title “National Distinguished Expert.”

Gopal Garg
SunPower Corporation

Gopal Garg is a “New Initiative leader” with a track-record of profitably incubating and scaling businesses by identifying market-trends, creating/acquiring global teams and partners, improving operational efficiency, and influencing change. Gopal is currently Vice President – Advance Solutions at SunPower Corporation that currently include Storage and Power Conversion. In addition, he serves as an Advisor to CREE high power devices, a venture-backed touch-solution company and Global Energy Systems Allainces. He is also co-chair of the TiE Silicon Valley Energy group. In his several roles as GM, Gopal has scaled businesses up to $300M from the ground up in a variety of markets—Renewable energy / Power Electronics, LED Lighting, Water Purification, Mobile Handsets, Enterprise Data communication, Consumer Goods, and Defense electronics. Gopal Garg has a B.E. from BITS Pilani, a premier private college in India, and an MBA from Punjab University in Chandigarh, India.

Ryan Harty
Honda

Ryan Harty is a mechanical engineer and Manager of American Honda’s Environmental Business Development Office (EBDO), where he is in charge of developing product proposals, business models, and policy proposals in support of Honda’s environmental initiatives. Current project include the “Green Dealer” program which reduces the energy use and environmental impact of Honda’s automobile dealerships, the Honda Smart Home US Program, which is demonstrating zero net energy use for housing and transportation using renewable energy while promoting sustainable building and design practices (hondasmarthome.com), and Honda’s US Solar Business and the collaboration with SolarCity. Ryan spent 10 years at Honda R&D, including pioneering work on hydrogen fuel cell and battery electric vehicles prior to his current assignment in EBDO. In his spare time, he enjoys curling at the Orange County Curling Club.

Armando Infanzon
San Diego Gas & Electric

Armando Infanzon is the Smart Grid policy manager for Sempra Energy's California regulated utility, San Diego Gas & Electric (SDG&E). Infanzon shapes the development of strategy and policy of Smart Grid initiatives and represents SDG&E on regulatory and legislative issues globally, national, locally and at the state level. Infanzon's prior positions at Sempra Energy include manager of international and regulatory analysis, where he oversaw economic, regulatory and political analysis for Sempra Energy's operations in Latin America. Infanzon was also manager of financial planning and analysis for Sempra Pipelines and Storage, a subsidiary of Sempra Energy engaged in natural gas infrastructure in North America, as well as manager of business valuation in the corporate development group. Prior to joining Sempra Energy in 1998, Infanzon worked for PriceWaterhouseCoopers and the First National Bank. Infanzon holds a master's degree in business administration from San Diego State University and a bachelor's degree in accountancy from the Autonomous University of Baja California.

Adam Langton
California Public Utilities Commission

Adam is the staff lead for the alternative-fueled vehicles proceeding at the California Public Utilities Commission. In this role, Adam advises the Commission on a range of issues aimed at increasing adoption of zero-emission vehicles for different transportation applications. Adam also supports the Governor's Office in designing and implementing the California Zero Emission Vehicle Initiative, including the CAISO-led effort to identify barriers to vehicle-grid integration. He was the lead technical analyst involved in developing the infrastructure components of the CPUC-NRG settlement, a $100 million investment in charging stations in California. He is also involved in the implementation of the carbon cap-and-trade program for California's electricity sector. Adam has a bachelor's degree in economics from Boston College and a graduate degree from the Goldman School of Public Policy at UC-Berkeley. Prior to graduate school, Adam was an analyst at the U.S. Office of Management and Budget, analyzing surface transportation programs and regulations.

Ryan McCarthy
California Air Resources Board

Ryan is the Science and Technology Advisor to the Chair at the California Air Resources Board, where he primarily focuses on transportation, energy and climate policy issues. Prior to his appointment at ARB by Governor Jerry Brown, McCarthy was chief writer of Taking Charge, a strategic plan for accelerating electric vehicle markets in California produced by the California Plug-In Electric Vehicle Collaborative. He was a Science and Technology Policy Fellow of the California Council on Science and Technology, where he worked in the office of California Assembly Member Wilmer Amina Carter and advised her on energy, environmental, and transportation issues, among others. McCarthy holds master's and doctorate degrees in civil and environmental engineering from UC Davis, and a bachelor's degree in structural engineering from UC San Diego.

Michael Moyer
Sumitomo

Michael graduated from Eastern Michigan University with a degree in Business Management. He worked as a Purchasing Manager (CPM) for Lenawee Stamping Corporation (part of Mazda) until 1997. He then went to Sumitomo Corporation of America, as a Product Manager, in charge of automotive equipment sales, including assembly lines and industrial robots. In 2010, he joined the US task force to promote 4R Energy Corporation, which is a joint venture between Sumitomo and Nissan in Japan. 4R looks for a second life use for Lithium ion batteries coming out of the all-electric vehicle, the Nissan LEAF.

David N. Patterson
Mitsubishi Motors

Mr. Patterson is Chief Engineer responsible for Mobile Emissions Certification and Regulatory Affairs maintaining Mitsubishi Motor's vehicle environmental compliance. He began his professional career with the California Air Resources Board. Among his varied assignments, he evaluated the first generation of electric and hybrid vehicles. He left state service to work with solid oxide and hydrogen fuel cell systems. In 2004, Mr. Patterson joined Mitsubishi Motors R&D of America. Mr. Patterson was a founding member of the US i-MiEV project responsible to bring Mitsubishi Motors electric vehicles to North America. Currently, he works toward the US introduction of the Outlander PHEV and evaluating V2X technologies to the US. Dave attended California State University Fresno and obtained a BS Mechanical Engineering. He is a Professional Engineer of Mechanical Engineering, Vice President of the Coordinating Research Council, and a member of the Society of Automotive Engineers.

Beth Reid
Olivine

Beth Reid is the CEO of Olivine and worked for over 15 years in the energy industry, including senior management positions at multi-national corporations such as ABB and VECTRA Technologies. Most recently, she has been focusing on helping clients develop cost-effective solutions in the areas of demand response, renewable resource utilization, and other environmental topics. Having worked in both the retail and wholesale sectors, most recently as Managing Director at APX, responsible for the Demand Response and Professional Services group, the breadth of Beth's experience enables her to bring a unique and valuable perspective to client collaborations. Beth holds a Masters of Business Administration degree from the University of Washington and completed her undergraduate degree work with a specialty in Economics at the University of Michigan.

Bradley Smith, Jr.
Nissan North America

As General Manager at US4R, Mr. Smith is leading the development of a new business utilizing used Nissan EV batteries in non-automotive (stationary) systems, so called "second life" applications. Brad and his team work closely with Japan-based 4R Energy Corporation, a joint venture between Nissan and Sumitomo. Additionally, as a dual-role Director, Brad serves as Nissan North America's Overseas Program Director for EV – primarily LEAF. Previous to joining Nissan in 2012 Brad was Director of Business Development at eVgo, a division of NRG Energy Inc., working with global automakers, charging hardware manufacturers and others in the EV infrastructure industry. His electric-drive and alternative fuels interest began in 2000 as Global Asset Development and Operations Manager at Shell Hydrogen working with automakers and other stakeholders to develop several "industry firsts" hydrogen fueling stations. He received his BS in Mechanical Engineering from South Dakota School of Mines & Technology and earned a Professional Masters of Business Administration degree from the University of Houston. Brad is a registered Texas Professional Engineer.

Dirk Spiers
ATC New Technologies

Dirk Spiers is the founder and director of ATC New Technologies and a pioneer in the repair, remanufacturing and refurbishment of advanced battery packs as well as the repurposing and second life of modules and cells. ATC New Technologies are the leaders in the refurbishment and repair of high voltage powertrain systems parts such as (P) EV battery packs, the reverse logistics of high voltage battery systems, advanced services like cell grading based on in-house developed systems and technologies. Their state-of-the-art battery centre is based in Oklahoma City where they work on the battery packs of all the leading players. They expect to open an additional facility in California in 2014. In addition, ATC New Technologies manufactures stationary Energy Storage Systems populated with both new and second life cells and modules. Dirk is also the founder of the Oklahoma Cell Exchange™ (OKcellX.com), the leading trading platform and exchange for secondary battery cells.

Dean Taylor
Southern California Edison

Dean Taylor is a manager and scientist at Southern California Edison in the electric transportation area, where is works on technical and strategic analysis as well as regulatory and legislative policy for the last 21 years. He has been involved with battery EVs since 1991 and plug-in HEV analysis and research since 1995. He has co-lead or chaired several legislative or technical coalitions or task forces for the industry, including the federal ad hoc PHEV and BEV coalition that worked on the Energy Independence and Security Act of 2007, the California EV Task Force, and the Hybrid Electric Vehicle Working Group. He has over 15 years experience in creating or co-managing legislative coalitions that resulted in over 50 bills being signed into law. He has project managed dozens of technical studies covering over 30 electric drive technologies, including non-road vehicles, high-speed rail, and heavy duty vehicles. His chapter on plug-in vehicle federal policies was published in 2009 by the Brookings Institute Press, and he has many other publications. He has a Bachelor of Science Degree in Environmental Science, Policy Analysis and Planning from the University of California, Davis.

John Tillman
Manager of Regulatory Affairs, Mercedes-Benz

John Tillman is the Manager of Regulatory Affairs for Mercedes-Benz Research and Development North America and is involved in government regulatory activities around e-Mobility and development of long term scenarios and strategies for introduction of advanced vehicle technologies into the US marketplace. Prior to joining Mercedes-Benz, John was involved in sustainable transportation and e-Mobility technologies at Volkswagen, Hyundai, and the UC Davis, Institute for Transportation Studies (ITS). At Volkswagen John was the Head of Advanced Powertrain Research and managed US research efforts in hydrogen fuel cell, battery electric vehicles, electric charging infrastructure and biofuels. At Hyundai he held the position of Program Manager for the US electric vehicle fuel cell program and developed their understanding and response to ZEV regulations and California GHG emissions policies. At UC Davis ITS, John served as Program Manager for the Toyota Hydrogen Fuel Cell Vehicle Program. John has Bachelor of Science degrees in Chemical and Electrical Engineering from UC Davis.

Ichiro Sugioka
Volvo

Ichiro Sugioka is the Science Officer at Volvo Monitoring and Concept Center (VMCC). He oversees strategic planning and scientific support of concepts developed at VMCC in Camarillo, California, USA. VMCC is a think tank Volvo Car Corporation's senior management. Besides managing the propulsion technology in all cars designed at VMCC, Ichiro works with product strategists in Sweden on alternative fuel and electric vehicles. This includes the study of all issues related to plug-in hybrid vehicles since the ECC in 1992. Prior to joining Volvo in 1994, Ichiro served as Principal Engineer at California Institute of Technology's 10-foot Wind Tunnel. During his 3 year tenure, he supervised the aerodynamic development of various transportation and architectural projects including cars for various OEMs, including the Volvo ECC and S80. Ichiro graduated with honors from California Institute of Technology in 1983. He also holds a doctorate from Caltech (1991) and a masters degree from MIT (1985), both in aeronautical engineering.

Pablo Valencia
General Motors

Pablo Valencia, currently the Senior Manager for Battery Lifecycle Management, joined General Motors in 1984, shortly after graduating from Michigan State University with a Bachelor of Science degree in Mechanical Engineering. Pablo has held various engineering positions in Powertrain, Thermal, and Advanced Technology Development including responsibility for Volt Battery Thermal and Mechanical systems. Pablo has also held several Business Positions at General Motors including Advanced Vehicle Line Manager for the Pontiac Solstice and a Product and Manufacturing Management Position for a GM Project in Torino Italy. Today, Pablo leads a cross functional team that is managing the cross program traction power battery life cycle activities including Service Strategy, Secondary Use, and Recycling.

Byron Washom
University of California, San Diego

Byron Washom is UC San Diego's founding Director of Strategic Energy Initiatives and is responsible for energy management policy to achieve the campus' goals for quantum improvements in energy management and Greenhouse Gas reductions. Prior to UCSD, Mr. Washom was the CEO for twenty years of a due diligence firm that specialized in CleanTech, and he served as Sr. International Advisor to the World Bank and DOE. He is a four time Rockefeller Foundation Grantee and a former Heinz Endowment Grantee for early commercialization of CleanTech into developing countries. Mr. Washom was also Founder and President of Advanco Corp which in 1984 set the long-standing world records for solar electric conversion efficiency at 29.4% and subsequently achieved an R&D100 Award. He was the 2008 Recipient of UCSD's Citizen of the Year Award for Sustainability, and he was a Visiting Faculty Member at the Rady School of Management while teaching the graduate level course, The Business of Renewable Energy. Fast Company magazine named him to their June cover story, "100 Most Creative Persons in Business, 2010", and he also received the "CleanTech San Diego Leadership Award, 2013".

Randall Winston
Office of Governor Edmund G. Brown, Jr

Randall Winston is Special Assistant to the Executive Secretary in the Office of Governor Edmund G. Brown, Jr working on environmental and energy policy and international affairs. He has worked in the areas of architecture, urban development, venture technology and finance, and worked for architect Norman Foster in New York prior to joining Governor Brown's office. Randall was a founding director at Causes, a venture technology company started by Facebook's founding president, and worked for SOHO China, an integrated urban development and architecture firm in Beijing, China, as well as for Goldman Sachs Gao Hua Securities, a China mainland joint-venture with Goldman Sachs. Randall received a B.A. in Government from Harvard University and a Master of Architecture degree from the University of Virginia.

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