PERSPECTIVE

The energy-storage revolution

Lithium-ion batteries enabled smartphones to flourish. The next innovation will upend transportation and the grid, says **George Crabtree**.

In 1991, the year that the lithium-ion battery was commercially released, no one foresaw the disruption that it would cause in personal electronics. After initially being used in portable music players and camcorders, lithium-ion batteries later found their way into, and spurred the development of, laptops, tablets and mobile phones — technologies that have permanently changed how much of society works.

Yet there is an even bigger revolution on the horizon. In the same way that telephones had a rotary dial for most of their existence, the electricity grid and cars have mostly existed in a single, unchanged format. But as we move beyond lithium-ion technology, a new generation of cheaper and more powerful batteries will completely rejig the power grid and usher in an age of electrically powered transportation.

Electric cars will replace imported oil with domestic electricity, use as little as one-fourth of the energy of petrol-driven cars per kilometre, emit significantly less carbon than conventional cars and, like mobile phones, provide a platform that supports apps that can do far more than just move the vehicle.

When both the drivetrain and the computer controlling it are electronic, it will be easier for them to communicate, so smart electric cars will know the traffic ahead, decide when to change lanes or choose alternative routes, find and pay for parking, program your driving calendar so that your itinerary saves energy and time, schedule the next charge based on your driving day and, ultimately, take over driving completely, doing it more effectively and safely than humans while freeing drivers for more productive and interesting tasks. Speciality cars for uses such as commuting, weekend errands, family events or long holidays may replace today's general-purpose cars. For many, car ownership itself may be replaced by renting or sharing on a need-to-use basis. Transportation will be personalized in the same way that mobile phones have personalized communication and information.

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The energy-storage revolution will also shake-up the electricity grid. Access to adequate amounts of cheap energy storage will break the constraint that power must be generated at the same rate that it is used. Instead, we will have a 'bank' for electricity that can accept deposits and withdrawals at any time. Such flexibility is essential if renewable electricity is to become widely deployed.

Inexpensive energy storage will allow customers to 'draw off' electricity when it is cheap, such as in the middle of the night, and store it until they need it. And if the customer has local power generation, such as a solar panel on the roof, smart technology will switch between drawing power from the grid, the solar panel or local batteries and storing electricity, thus improving efficiency and lowering the cost of electricity use.

Currently, excess energy generated by local solar panels is sold back into the grid, and the homeowner uses grid electricity when the sun is not shining. But in the future, power from solar panels could be stored locally and used later — so the homeowner might rely much less on the main grid, instead relying on their own 'microgrid'. A neighbourhood of homes sharing a large common battery would constitute an even more cost-efficient microgrid thanks to the economy of scale.

Commercial buildings, university campuses, factories and military bases would have different needs, requiring microgrids designed with their own special mix of storage, generation and use. Such diverse microgrids could serve their customers much more effectively than the one-size-fits-all approach of centralized utilities without storage.

A distributed, interacting network of microgrids would enable higher reliability, flexibility and resiliency, as well as security. A thunderstorm, hurricane or terrorist attack would not disable power for the entire network. Instead, surviving microgrids would share stored power with power-less neighbours.

How big will these changes be in energy and financial terms? In the United States, personal electronics account for about 2% of energy use, and make up most of the lithium-ion battery market, which is worth between US$15 billion and $20 billion; transportation and the grid together account for nearly 70% of electricity use. If half of this transportation and grid energy was channelled through storage this would create a market of more than 15 times the current size.

What would it take to achieve these game-changing outcomes? One innovation: high-performance, inexpensive electricity storage. Simple estimates suggest that improvements in performance and cost of around fivefold are needed to enable an inexpensive electric car with a range of hundreds of kilometres, the replacement of fossil-fuel power plants with wind, solar and stored electricity, and the installation of compact, distributed storage in urban areas where land is expensive.

These fivefold improvements will not come from incremental advances in today's lithium-ion technology; they will require conceptual innovations and qualitatively different approaches that go beyond lithium-ion technology. There are many promising avenues, including multivalent batteries that use doubly or triply charged working ions in place of singly charged lithium, the replacement of intercalation at the anode and cathode with covalent chemical reactions, as in lithium–sulfur batteries, and a host of flow-battery concepts based on high-voltage organic electrolytes and polymer active materials.

Although the societal pay-offs of electrified transportation and smart storage on the grid are substantial, the ultimate path to their development is uncertain and the risk of failure is high. Greater efforts by research organizations that can tolerate that risk, such as universities and national labs, are needed to identify and develop the most promising opportunities for next-generation energy storage. As the winning technologies emerge, the private sector will engage and deliver them to the public. As was true of the lithium-ion battery at its introduction in 1991, the challenges and opportunities are vast, rich and mostly unexplored. ■

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