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New Scientist

Batteries of the future

In the present world which electrical batteries have enabled to become industrialised, electrolytes and electrodes have seemingly replaced society's notion of "bread and butter". But what will the future generation rely on?

By Taehan Lim

There is one striking familiarity between iPhones, laptops and cars largely dismissed by the average consumer. They contain batteries, or storage devices composed of cells; the chemical energy of which is used to derive electricity to power such appliances (Oxford University Press, 2018).

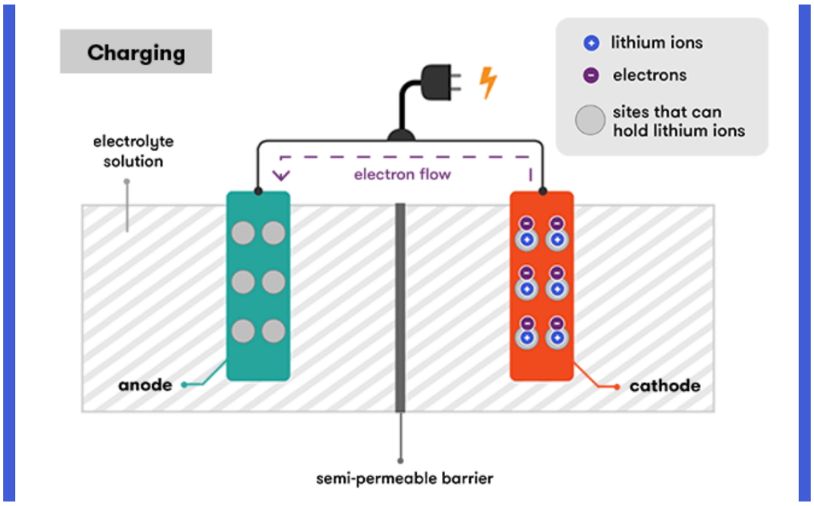
Ever since the advent of the Voltaic pile by Alessandro Volta in 1800, electrical batteries have undertaken vast leaps and thereby facilitated society's "electrifying" transition into a world of almost universal dependence on electricity (Bellis, 2018; Carter, 2018). Recently, there has been a surge in the need for improved energy storage devices as the toll of harmful human activities begins to distinctly manifest itself (Carter, 2018).

Society has been unwittingly heavily reliant on fossil fuel combustion at the expense of the environment for energy production since the Industrial (Wellers & Randers, 2018). They were an essential source of energy for a wide variety of purposes, varying from domestic heating to industrial uses. Despite attempts to falter the tides of time, this trend has largely persisted and today around 1 000 tonnes (2.4 million pounds) of the greenhouse gas carbon dioxide is emitted into the atmosphere every second (CBS, 2012). As discussed in the Paris Agreement, such practises must be constrained to maintain a global temperature rise below 2^{o}C since pre-industrial levels this century (UNFCC, 2015). According to the

Lawrence Livermore National Laboratory, more energy is wasted than used due to the by-product of heat from fossil fuel burning and inefficient transportation, among other reasons (Harrington, 2015). Any ambitions of preventing climate change are thus pre-destined to fall short of success without an appreciation of batteries.

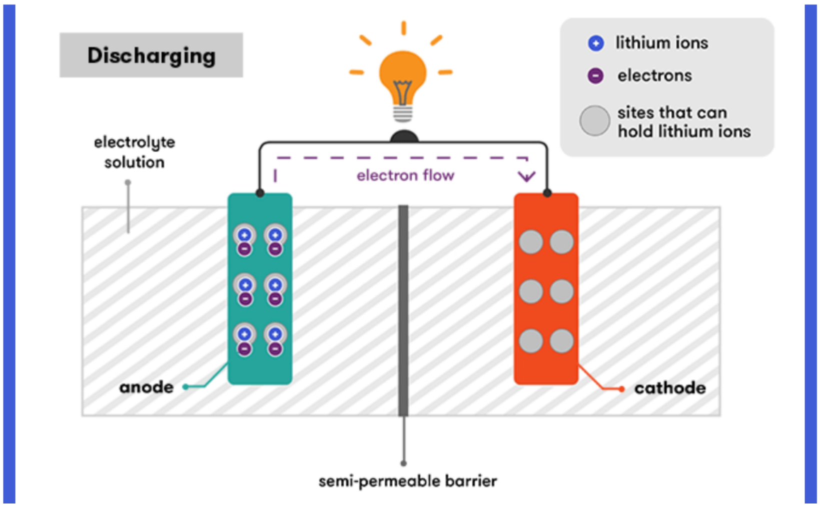
Renewable resources like solar power, wind power and hydroelectricity are a viable substitute for fossil fuels but their present utilisation is stymied by variability. Nonetheless batteries, in particular lithium-ion devices, are currently heralded as the technology to compromise this shortcoming. Composed of two electrodes (an anode and a cathode), an electrolyte of a mixture of lithium salts and solvents, an external wire and a semi-permeable barrier, it boasts of great potential (Australian Academy of Science, 2016).

The electrodes are composed of materials capable of intercalation, trapping charged particles in their structure. A lithium-ion battery commences its life in a state of full discharge, during which its lithium particles are intercalated within the cathode structure. Once charged, an oxidation reaction occurs at the cathode and hence, the electrons travel from the cathode to the anode by an external wire. To balance this, lithium cations dissolve into the electrolyte, from where they proceed through the semi-permeable barrier and intercalate within the anode while being stabilised by incoming electrons (Australian Academy of Science, 2016).



An illustration of a lithium-ion battery while charging. *Source: https://www.science.org.au/curious/technology-future/lithium-ion-batteries*

During discharge, the lithium cations de-intercalate from the anode and travel through the semi-permeable barrier until they intercalate within the cathode. The electrons, which previously tied them, relocate to the cathode via the external wire. The electric current (or electricity) generated by this movement can be employed by electric appliances (Australian Academy of Science, 2016).



An illustration of a lithium-ion battery during discharge. *Source: https://www.science.org.au/curious/technology-future/lithium-ion-batteries*

The design of the lithium-ion battery is laden with promise and has accordingly been embraced. Since it is a secondary battery, it can be recharged indefinitely until the graphite anode becomes dysfunctional. Moreover it is comparatively energy dense, lightweight and enjoys a greater lifespan than other models in the present (Bellis, 2017; Australian Academy of Science, 2016). The Tesla Lithium-ion batteries of the Hornsdale power reserve, located approximately 15km north of Jamestown in South Australia, are a noteworthy application of this device (Hornsdale Power Reserve, 2017). Completed in less than 100 days, the power reserve has proven to be crucial for its contributions to national frequency control ancillary services (Harmsen, 2018; Mc Connell, 2018). On the 18th of December, when a coal power generator tripped in New South Wales, the battery responded to the loss of 689 megawatts from the market in a split second. At home in South Australia, it satisfied demand peaks during the summer of 2017-2018 (Harmsen, 2018). Moreover, the power reserve's overall efficacy is supplemented by the Hornsdale Wind Farm, a neighbouring source of renewable energy; wind power (McConnell, 2018).

By the same token, highly developed battery technologies offer an opportunity to incorporate renewable energy more broadly into society. The unstated potential of renewable resources like wind power, solar power and hydroelectricity are difficult to refute (McLamb, 2010). Renewable energy's primary drawback, variability, can be combated by effective batteries which can store excess energy produced for extensive periods of time (UltraBattery, n.d.). To elaborate, solar panels are largely ineffective during even intermittent periods of sunlight absence, but effective batteries will permit private consumers to rely on stored energy to meet daily requirements during such occurrences. Excess energy produced may also be stored and released into the electric grid upon sufficient demand (Carter, 2018; McConnell, 2018). These features will ultimately reduce society's dependence on non-renewable energy resources.

Nevertheless, the tendency of lithium-ion batteries to explode is likely to restrict its role in the future (ScienceStruck, 2018). In the instance of a short circuit due to a breach in the semi-permeable barrier, the battery may be subject to temperatures in excess of 540^{o} C from commencing thermal runaway, whereby the temperature escalates further from the degradation of the barrier. The flammable electrolyte will ignite or explode from exposure to oxygen in such conditions, and this characteristic is responsible for the caution undertaken by airports and other facilities towards lithium-ion batteries. Besides exploding laptops and phones, various negative ramifications can eventuate from this trait. As Professor Forsyth from the Institute for Frontier Materials in Deakin University suggested, the future will largely be composed of an aged population, partially because of developments in modern medical science. This prediction can be numerically expressed in the 2 million individuals 60 years or older who will constitute 22% of the global population by 2050 (World Health Organisation, 2018). Electric prosthetic devices and pacers will consequently become commonplace aids for everyday activities with a greater demand than that of today (Forsyth, 2018). For these consumers, hazardous batteries are simply too precarious for prosthetic arms and legs.

Notwithstanding this, solid-state magnesium-ion batteries are an emerging technology with the potential to outstrip lithium-ion batteries in energy density. Essentially a redox battery, researchers from the Department of Energy's Lawrence Berkley National Laboratory and Argonne National Laboratory have been developing a magnesium battery with higher energy density than its lithium-based counterpart. It similar function contrasts to the theoretical studies and nuclear magnetic resonance spectroscopy experiments undertaken as of yet which validate the possibility of supplanting its predecessor. Moreover, the solid-state electrolyte would ensure that batteries are fire-resistant (Chao, 2017).

From the other end of the spectrum, a team of researchers at the Samsung Advanced Institute of Technology have created a material aptly dubbed “graphene balls”. When implemented into lithium-ion batteries, these “graphene balls” increased the capacity by 45% and increased charging speeds sixfold. Besides graphene ball-based batteries’ theoretical charging time of merely 12 minutes, they can maintain temperature stability; a necessary feature for electric vehicles (Samsung Newsroom, 2018). At the same time, graphene is the strongest compound and the lightest material known as of yet (Nicol, 2018).

The leader of this project, Dr Son In-Hyuk said “Our research enables mass synthesis of multifunctional composite material graphene at an affordable price. At the same time, we were able to considerably enhance the capabilities of lithium-ion batteries in an environment where the markets for mobile devices and electric vehicles is growing rapidly…….” (Samsung Newsroom, 2018)

Environmentally harmful methods of energy production enabled much of the world to develop and persist in doing so today in some less developed regions of the world. In this regard, such harmful methods of industrialisation were once crucial for society. Due to progressive developments in science, the age of ignorant reliance on adverse technologies has passed. It is thus necessary to replace such unsustainable and harmful practises with innovations conducive in the preservation of the environment, and batteries are a necessary component of the solution. The distant future is obscured by the possibility of yet greater innovation, even though the aforementioned developments are already exciting and promising. The crux of the issue is not a matter of battery innovation availability, but the willingness of society. The battery technology innovations at our disposal in the present should be adopted and researched more proactively; otherwise our only legacy imprinted in history for future generations may be “then”.

Bibliography

Australian Academy of Science (2016). *Lithium-ion batteries*. [online] Curious. Available at: https://www.science.org.au/curious/technology-future/lithium-ion-batteries [Accessed 19 Jul. 2018].

Bellis, M. (2017). *The Beginner's Guide to How a Battery Works*. [online] ThoughtCo. Available at: https://www.thoughtco.com/how-a-battery-works-1991356 [Accessed 19 Jul. 2018].

Bellis, M. (2018). *We're All Charged Up about This History of the Battery*. [online] ThoughtCo. Available at: https://www.thoughtco.com/battery-timeline-1991340 [Accessed 18 Jul. 2018].

Carter, J. (2018). *The future of our technology and our planet depends on one thing: the battery*. [online] TechRadar. Available at: https://www.techradar.com/au/news/the-future-of-our-technology-and-our-planet-depends-on-one-thing-the-battery [Accessed 18 Jul. 2018].

Chao, J. (2017). 'Holy Grail' for Batteries: Solid-State Magnesium Battery a Big Step Closer. *Berkeley Lab News Center*. [online] Available at: https://newscenter.lbl.gov/2017/11/28/holy-grail-batteries-solid-state-magnesium-battery-big-step-closer/ [Accessed 19 Jul. 2018].

Forsyth, M. (2018). *How batteries will change the way we use power in the future | this.*. [online] this. Available at: http://this.deakin.edu.au/innovation/how-batteries-will-change-the-way-we-use-power-in-the-future [Accessed 19 Jul. 2018].

Harmsen, N. (2018). How Elon Musk's big Tesla battery is changing Australia's power landscape. *ABC News*. [online] Available at: http://www.abc.net.au/news/2018-04-06/tesla-battery-outperforms-coal-and-gas/9625726 [Accessed 19 Jul. 2018].

Harrington, R. (2015). This chart shows where all the world's energy comes from -- and goes. *Business Insider*. [online] Available at: https://www.businessinsider.com.au/most-energy-still-comes-from-oil-2015-10?r=US&IR=T [Accessed 24 Jul. 2018].

Hornsdale Power Reserve (2017). *Overview – Hornsdale Power Reserve*. [online] Hornsdalepowerreserve.com.au.

Available at: https://hornsdalepowerreserve.com.au/overview/ [Accessed 24 Jul. 2018].

McConnell, D. (2018). A month in, Tesla's SA battery is surpassing expectations. *The Conversation*. [online] Available at: https://theconversation.com/a-month-in-teslas-sa-battery-is-surpassing-expectations-89770 [Accessed 19 Jul. 2018].

McLamb, E. (2010). *The Secret World of Energy | Ecology Global Network*. [online] Ecology Global Network. Available at: http://www.ecology.com/2010/09/15/secret-world-energy/ [Accessed 19 Jul. 2018].

Nicol, W. (2018). *https://www.digitaltrends.com/cool-tech/what-is-graphene-and-how-will-it-shape-the-future-of-tech/*. [online] Digitaltrends.com. Available at: https://www.digitaltrends.com/cool-tech/what-is-graphene-and-how-will-it-shape-the-future-of-tech/ [Accessed 19 Jul. 2018].

Oxford University Press (2018). Battery. In: *Oxford Dictionaries*. [online] Available at: https://en.oxforddictionaries.com/definition/battery [Accessed 18 Jul. 2018].

Samsung Newsroom (2018). https://news.samsung.com/global/samsung-develops-battery-material-with-5x-faster-charging-speed. [online] Available at: https://news.samsung.com/global/samsung-develops-battery-material-with-5x-faster-charging-speed [Accessed 19 Jul. 2018].

ScienceStruck (2018). *Advantages and Disadvantages of Lithium-ion Batteries*. [online] ScienceStruck. Available at: https://sciencestruck.com/advantages-disadvantages-of-lithium-ion-batteries [Accessed 19 Jul. 2018].

St. John, A. (2016). *Why Lithium-Ion Batteries Still Explode, and What's Being Done to Fix the Problem*. [online] Consumer Reports. Available at: https://www.consumerreports.org/safety-recalls/why-lithium-ion-batteries-still-explode-and-whats-being-done-to-fix-the-problem/ [Accessed 24 Jul. 2018].

UltraBattery (n.d.). *Why Energy Storage? | UltraBattery*. [online] Ultrabattery.com. Available at: http://ultrabattery.com/why-energy-storage/ [Accessed 19 Jul. 2018].

UNFCC (2015). *Historic Paris Agreement on Climate Change: 195 Nations Set Path to Keep Temperature Rise Well Below 2 Degrees Celsius | UNFCCC*. [online] Unfccc.int. Available at: https://unfccc.int/news/finale-cop21 [Accessed 19 Jul. 2018].

Wellers, D. and Randers, M. (2018). *How Future Batteries Could Save Civilization*. [online] Digitalistmag.com. Available at: https://www.digitalistmag.com/digital-economy/digital-futures/2018/01/04/how-future-batteries-could-save-civilization-05644661 [Accessed 19 Jul. 2018].

World Health Organization (2018). *Ageing and health*. [online] World Health Organization. Available at: http://www.who.int/news-room/fact-sheets/detail/ageing-and-health [Accessed 24 Jul. 2018].

CBS (2012). *CBS News*. [online] Available at: https://www.cbsnews.com/news/carbon-dioxide-emissions-rise-to-24-million-pounds-per-second/ [Accessed 24 Jul. 2018].