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DISRUPTIVE
INSIGHTS

CUTTING THE CORD

FOCUSING ON THE FUTURE

The biggest weapon in any investor's arsenal is knowledge. The financial industry and media generally do a good job of helping investors understand the implications of near-term news that may move markets. However, focusing solely on the short-term can handicap investors, leading them to miss the larger trends that have the power to change society and drive significant moves in the market going forward. With that in mind, this edition of *Disruptive Insights* focuses on what a significant improvement in energy storage technology could mean for the world, and discusses some of the technologies under development that may help lead to such a future.

LPL Financial

> AN ECONOMICAL WAY TO STORE THE ENERGY GENERATED BY RENEWABLE MEANS WOULD INDICATE THAT USERS ARE NO LONGER DEPENDENT ON THE GRID.

WHY DOES BATTERY TECHNOLOGY MATTER?

Imagine a car that can drive from Miami to New York without refueling, the ability to power your home at night using energy collected by solar panels during the day, or even something as simple as a smartphone that can run for five days without charging. Advances in battery technology could make these and any number of other innovations possible in the future. Figure 1 shows the potential impact on a number of devices in use today.

While a cell phone that lasts five days would be convenient and likely very profitable for the company selling it, it doesn't fully demonstrate the potential changes that battery technology could usher in. One of the broadest markets a better battery could impact is energy generation and storage. Solar and wind power have come a long way in recent years, but they still have a big problem—if the sun isn't shining or the wind isn't blowing, they can't generate power. However, having an economical way to store the energy they generate would mean users are no longer dependent on the grid.

Several companies have already entered this market using currently available technology, but cheaper or more powerful storage technologies could enable the widespread usage of renewable energy. Outside of profits for properly positioned companies (which could be huge), this shift could be life-changing for people in areas of the world that don't have a reliable power system. However you look at it, overcoming the drawbacks of current battery design has the potential to unleash massive improvements for our world, along with significant changes to economies and financial markets.

See page 07 for potential sector implications

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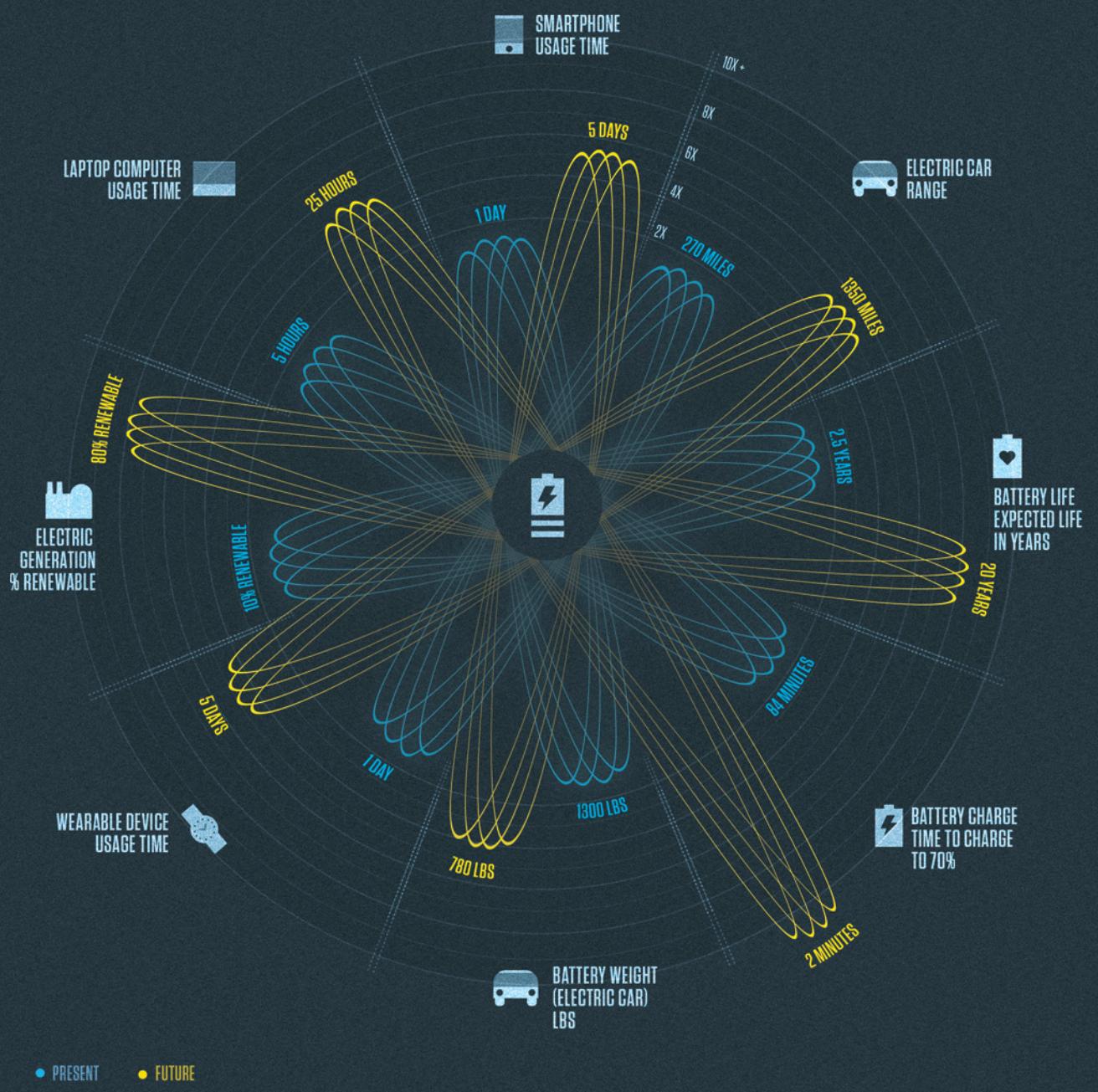
CUTTING THE CORD
THE IMPACTS OF A BETTER BATTERY

PRESENT & FUTURE

Battery technology hasn't kept pace with other technological innovations, though several technologies under development hope to be the next breakthrough. This graphic shows the impact a better battery could have on the devices used in daily life.



Scale legend: A longer future line represents a larger potential improvement. Lines are scaled based on a multiple of the "today" metric for each item.

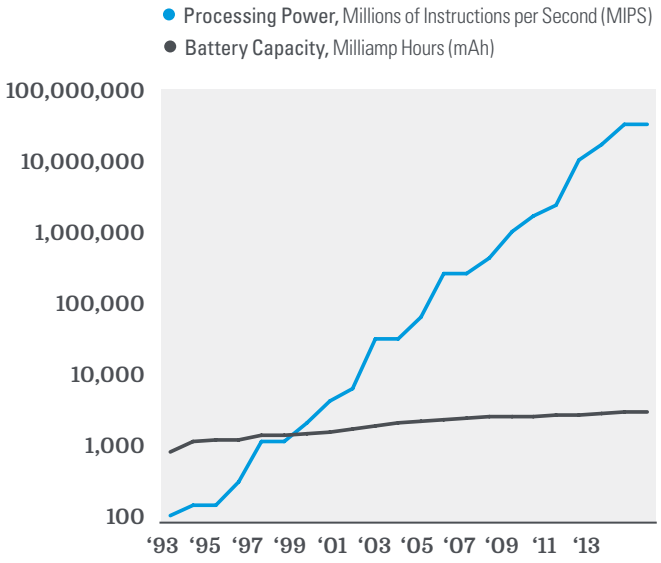
Source: LPL Research, www.Nature.com, EIA, Nanyang Technological University, www.GreenCarCongreess.com 07/21/15

WHY AREN'T WE THERE YET?

While many of the technologies underpinning the devices we use continue to advance at a blistering pace, battery technology is an exception. Gordon Moore, co-founder of Intel, made a statement in 1965 (called Moore's Law) which, at a high level, says that the processing power of computers doubles every two years. This prediction has largely held true over time, and the increase in computing power over the last 50 years has been astounding. A smartphone small enough to fit in a pocket today is thousands of times more powerful than the computers that helped put the first man on the moon.

Unfortunately, Moore's law doesn't apply to batteries. In fact, the batteries used in today's high-tech devices are based on a design developed more than 200 years ago. The first true battery was invented in 1800, and even the widely used lithium-ion battery, which powers everything from cell phones to electric cars, was originally commercialized in 1991. This is not to say that the technology hasn't improved over time, or that it can't continue to improve—it certainly has and can—but battery technology hasn't kept pace with broader technological innovations. Figure 2 shows the wide disparity between increases in computing technology and battery capacity over time.

2 BATTERY TECHNOLOGY HAS NOT KEPT PACE WITH BROADER TECHNOLOGICAL INNOVATIONS



Source: LPL Research, www.Top500.org, www.electronicdesign.com 07/10/15

Vertical axis is log (base 10).

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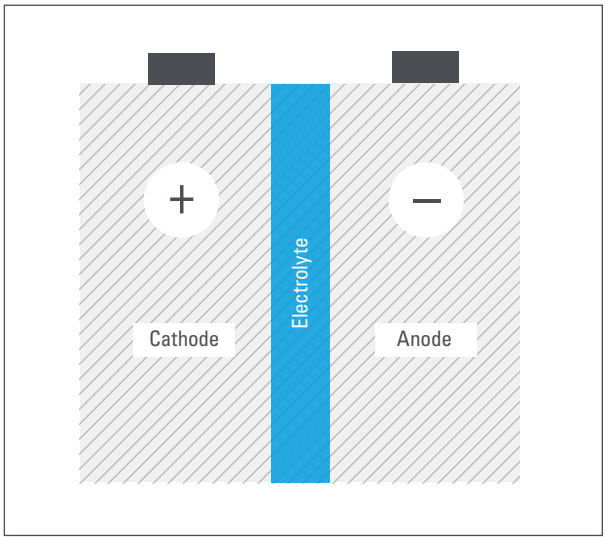
WHAT'S NEXT IN BATTERY TECHNOLOGY?

Lithium-ion technology is by no means dead. In fact, a widely publicized effort aims to build a single factory that by 2020 intends to produce as many lithium-ion batteries as the entire world produced in 2013, while also reducing costs by 30%. At this point no one knows if these goals will be met, but it does show that companies are willing to continue investing in the technology.

Lithium-ion, however, is also not the only technology being pursued. A few additional technologies currently under development are discussed in the following pages.

Understanding the benefits of these technologies is easier with a basic understanding of how a battery works. A battery doesn't store electricity directly, but rather creates electricity as a result of chemical reactions between the different substances within it. There are three parts to any battery, an anode (think of the negative terminal on a car battery), a cathode (positive terminal), and an electrolyte. The electrolyte allows an electrical charge to flow between the cathode and the anode (both of which are typically a metal). Figure 3 diagrams this setup.

3 A BASIC DIAGRAM OF A BATTERY



Source: LPL Research, University of Washington 07/10/15

LIQUID BATTERIES: A SOLAR PANEL'S BEST FRIEND

For situations where weight isn't an issue, liquid batteries offer an interesting solution. Rather than using a metal for the anode and cathode, these types of batteries use liquids. One design in particular, the vanadium flow battery, uses a unique substance that is able to hold either a positive or negative charge. Because the cathode and anode are made of the same material, they don't cause reactions that degrade the capacity of the battery over time. The main benefit of this type of battery is its long life. A typical lithium-ion battery can be cycled (discharged and recharged) somewhere in the neighborhood of 500 times (2–3 years of use), while a flow battery can cycle 5,000 or more times (20 years of use) before seeing a degradation in performance. However, flow batteries are more expensive than their lithium-ion counterparts, operate best in a relatively small temperature range, and their weight means portable applications don't make sense. Flow batteries have been in use for some time, mainly by utility companies and other providers that need long life but not portability; however, the aforementioned problems have kept them from hitting the mainstream. Researchers claim to have developed new processes that will fix these issues and make flow batteries more affordable, but even if these ideas pan out, flow batteries are still at least several years away from wider usage. That being said, a cost-efficient flow battery could lead to a world in which utilities focus more on renewable energy, or even one that allows consumers to bypass utilities completely by installing their own power generation and storage systems in their homes.

AIR BATTERIES: REDUCING WEIGHT FOR PORTABLE APPLICATIONS

An air battery uses oxygen collected from the surrounding air as the material for the cathode, instead of a metal. This design allows additional anode material to be stored, creating a battery with the same weight but significantly increased capacity. Researchers believe that a lithium-air battery could hold 10 times more energy than a current lithium-ion battery of the same weight, which would be especially impactful for applications where weight is an issue, such as electric cars. For example, one of the more well-known electric cars today is the Tesla Model S, which claims a maximum range of 270 miles. Assuming a lithium-air battery could result in even a fivefold increase in energy capacity, multiplying the current range by five would get us to a range of 1,350 miles, nearly double that of today's longest range of internal combustion vehicles. While various types of air batteries are being tested in real-world conditions, widespread availability is probably at least a few years away. But a significant improvement in range could help electric cars overtake their internal combustion counterparts, leading to a shakeup in not only the auto industry, but supporting industries such as oil exploration/distribution and utility companies.

SUPERCAPACITORS: QUICK CHARGE AND LONG LIFE

Capacitors, first invented in 1745, have been around even longer than batteries. Capacitors differ from batteries in that they are used to store small amounts of electrical energy directly. Supercapacitors, as the name suggests, store a larger amount of electricity than a standard capacitor. They also have a number of benefits compared with batteries, including the ability to charge and discharge nearly instantly (for this reason they are often used in regenerative braking systems on larger electric vehicles, such as buses), longer lifespans (millions of cycles compared with the aforementioned 500 for a lithium-ion battery), and a better safety track record because they don't rely on chemical reactions. However, despite these advantages, supercapacitors have not historically been a direct competitor to batteries because of high cost and capacity shortfalls versus batteries of similar size and weight (for comparison purposes, a lithium-ion battery can hold approximately 20 times as much energy as today's supercapacitors). Continued advancements in production technology, including a new cost-effective process to create tiny supercapacitors with graphene, may help lower costs and potentially even double or triple capacity within a couple of years. This wouldn't make supercapacitors directly comparable with batteries in the near term, but their ability to enable devices with instant charging and longer lifespans would be a welcome win for consumers.

IMPROVED CHARGING TECHNOLOGY MAY REDUCE DOWNTIME

Improving charging technology is another way to improve the usefulness of batteries, and several paths are being explored. The idea of wireless charging has been around for more than 100 years, but the amount of electricity that can be transferred is relatively small, and devices have to be very close to the base station—though one can imagine how improvements in this area could potentially eliminate issues of battery capacity. Other interesting ideas that may move the needle include making lithium-ion batteries charge faster and last longer (Nanyang Technology University in Singapore is currently working on a lithium-ion battery that will charge to 70% capacity in 2 minutes and last for 10,000 cycles), shoes that generate an electrical current when you walk (which could be used to charge devices), and self-charging batteries, the holy grail of charging technology. None of these technologies are ready for prime time, but creating a self-charging mobile device or lowering the time to charge an electric car to be on par with refueling would have major implications.

WHAT INVESTORS SHOULD KNOW

It's easy to find announcements of breakthroughs in battery technology, but also just as easy to find stories of suspected breakthroughs failing to live up to the hype because technologies that work under strictly controlled lab conditions don't always work so well in the real world. Additionally, testing designs in real-world settings is very expensive and time consuming; but this testing is also very important, given that a flaw could lead to an explosion or fire (and serious injuries), rather than just a dead smartphone. And while battery technology is the main focus of this article, it is also important to remember that technological innovations in other areas could have similar impacts. For example, if advances in wireless charging allow it to be as widespread as wireless internet is today, or advances in fuel cell technology make affordable, portable electricity generation possible, then a better battery may become less important. Given the potential for profits, it is likely that money will continue to flow into battery research, and at some point a breakthrough will probably happen. However, the number of failures will likely far exceed the number of successes, meaning investing in the industry is not for the faint of heart. Figure 4 identifies four sectors that may be impacted by a breakthrough in energy storage, and potential implications.

Nonetheless, battery technology is set to improve, allowing society to continue to cut the cords (literally and figuratively) that have historically held it back in areas ranging from mobile productivity, to transportation, and even the widespread use of renewable energy. Transformations in each of these categories hold the promise of positive ramifications for the economy and, in turn, financial markets. ■

4 POTENTIAL SECTOR IMPLICATIONS OF A BETTER BATTERY

Industry	Potential Positive Impacts	Potential Negative Impacts
Utilities	Renewable power becomes affordable, potentially lowering costs over time.	Consumers could choose to install their own solar or wind power and storage systems, bypassing utilites completely.
Energy	Increased sales for renewable energy and energy storage manufacturers.	Fossil fuels lose market share, reducing sales for industries from energy exploration to distribution.
Consumer Discretionary	Opportunity for companies that manufacture electric vehicles.	Existing companies that can't compete in the electric vehicle arena lose market share.
Technology	Device makers can create mobile devices with longer battery life and longer life expectancy.	Pace of innovation may need to increase in order to maintain sales, as deterioriating battery life will no longer drive upgrades.

Source: LPL Research 07/10/15

Because of their narrow focus, specialty sector investing, such as healthcare, financials, or energy, will be subject to greater volatility than investing more broadly across many sectors and companies.

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IMPORTANT DISCLOSURES

The opinions voiced in this material are for general information only and are not intended to provide or be construed as providing specific investment advice or recommendations for your clients. Any economic forecasts set forth in the presentation may not develop as predicted and there can be no guarantee that strategies promoted will be successful.

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