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Smart Energy

The Future of Power Storage

Darren Beck

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by Darren Beck

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

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Production Editor: Kristen Brown
Copyeditor: Kim Cofer
Interior Designer: David Futato
Cover Designer: Karen Montgomery
Illustrator: Rebecca Demarest

November 2015: First Edition

Revision History for the First Edition

2015-11-04: First Release

978-1-491-93971-0

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CHAPTER 1

Smart Energy Solution

Electricity is essential to modern life. More than four-fifths of the world's population has access to it according to the International Energy Agency, and in the US, it is so pervasive we often take it for granted. Whether we're preparing our meals, drying our clothes, charging our mobile phones, or powering our alarm clocks, we're using electricity at all hours of the day—often without considering how it's made, how much we use, and how else the system could work. What if that could change?

Imagine having a range of new choices and insights to help you make smarter decisions about energy use. For instance, would it be possible to train your house to always know how to achieve the right temperature whether you're at home or away? Could you bestow your office with the ability to provide the right amount of light anywhere, anytime, in the building, automatically? What about being able to divine when the cleanest energy was being to transmitted to you and charge your electronics at those times? Could you even find a way to capture and store the sun's energy and then use it at night?

Thanks to advancements in technology and connectivity, our options for "smart energy" abound. It's now possible to maintain the upside of traditional energy (reliability and coverage), while reducing its downside (high cost, inefficiencies, and a heavy reliance on fossil fuels). Internet-enabled devices, the latest in energy production technology, and advancements in power storage solutions are forming the backbone of a new smart energy marketplace. They are enabling more of us to take an active role in it. Informed by streams of intelligence and empowered by these resources, we can now produce, trade, and consume electricity with more efficiency, lower cost, and greater sustainability.

Enabled by the IoT

Whether you're producing electricity or consuming it, making informed decisions about energy is a lot easier today. A network of agents—the Internet of Things (IoT)—exists that can help you with that task. These agents come in the form of meters and sensors deployed throughout the electrical grid and in homes and businesses. They gather a myriad of data, connect to the Internet, and transmit the data to cloud-based applications where it can be aggregated, analyzed, and compared with other data sets. The result is information that can help you to decide how best to power your life and livelihood while saving money and minimizing impact on the environment.

For example, most utilities deploy a network of wireless sensors between their facilities and their customers' meters to monitor energy flow. These devices have replaced the "meter men" of old and provide real-time data on power demand, supply, and outages. When analyzed along with historical data, it enables utilities to spot trends. Combine it with third-party intelligence like forecasts on weather, fuel availability in the commodities market, or population growth, and it helps them to optimize energy production and adjust the technology in their portfolio.

This helps utilities to become more energy-efficient, saving them money and reducing their carbon footprint. Likewise, customers have an array of IoT solutions to help them achieve the same "behind the meter." For example, today you can buy temperature control systems that are able to learn and adapt. Nest, a residential solution, and Comfy, a solution geared more toward the business environment, can automatically adjust indoor heating and cooling to the desired level. As you teach the systems your preferences, they quickly adapt, analyzing and making adjustments to the settings on their own to optimize comfort and energy use.

Another example is intelligent lighting systems, like the commercial wireless solution offered by Daintree. In a business facility, all spaces are not occupied equally all of the time. For instance, most offices only conduct business during the day. These systems can be programmed to turn on, turn off, or dim lighting at preset times to accommodate business hours. They also use a variety of sensors, including motion and thermal detectors, to determine when a conference room is occupied and lights should be on. In addition, some systems use ambient light sensors. They determine how much sunshine a room is already receiving and adjust the indoor lighting accordingly.

Lastly, what if you want to use the cleanest energy available on the grid at any given time? WattTime, a nonprofit devoted to solving this challenge, has developed a solution that can be incorporated into any Internet-enabled product that draws electricity.

"Every time you flip a switch or your equipment turns on, some power plant has to increase its electricity output right away—the 'marginal' plant," explains Gavin McCormick, co-founder and executive director of WattTime. Which power plant is marginal? The answer is constantly changing, up to every five minutes. "We provide a service to sync the moments your smart devices draw energy to match the moments when your local marginal power plant is a cleaner one," said McCormack.

WattTime estimates your local marginal plant and its cleanliness by matching public power grid information with the U.S. Environmental Protection Agency's Continuous Emissions Monitoring System. It's being used today in conjunction with electric vehicle charging stations sold by eMotorWerks. Another big opportunity McCormack sees is pairing it with smart thermostats. "In most cases it is possible to reduce the carbon footprint from electric heat and air conditioning with essentially zero impact on user comfort or their energy bill."

These IoT-based energy solutions provide awareness and optimization. They enable producers to operate more efficiently by offering insights into real-time demand, analysis for making more accurate predictions, and automation to adjust power generation accordingly. They also enable customers to learn when, where, and how much energy is needed, understand options for sourcing it, and automate usage to achieve optimal energy efficiency based on personal preference. This intelligence and capability is essential to ushering in a new era. However, the vision for smart energy only realizes its full potential when the Internet of Things is combined with advancements in energy production and storage technologies.

Fueled by Advancements in Power Technology

We've seen how smart energy solutions can help utilities better anticipate demand and enable customers to pare back energy use. This creates positive results even in a traditional marketplace where all of the power is generated by the utilities and is based on fossil fuels. Each party saves money and benefits from releasing fewer greenhouse gas emissions into the atmosphere. The good news is that there's even more to be gained by pairing these solutions with new technologies that empower anyone to produce clean, renewable energy and use it at the optimal time.

Here's why clean production is paramount to smart energy. It's the most viable path for sustainability, and it addresses the power industry's major contribution to global warming. According to the CAIT Climate Data Explorer, an open source database developed by the World Resources Institute that contains well-founded data on climate change, "Electricity & Heat," a subsector of Energy, contributed nearly a third of the global greenhouse gas emissions released in 2012.

This oversized impact is due mostly to the industry's reliance on fossil fuels—primarily coal. These limited resources are not renewable on a human timescale and are comparatively heavy polluters.

Figure 1-1 shows data from the National Renewable Energy Lab (NREL) study of the life cycle greenhouse gas emissions for select energy technologies from "cradle to grave." This table shows the median emissions estimated for each technology based on public data, some of which they were able to harmonize. What comes through clearly is the stark difference between fossil fuels and all other technologies listed.

Natural gas and coal contribute at least nine times more greenhouse gas emissions to the atmosphere over their lifetime. When comparing coal to hydropower, it's as much as 143 times more. Ideally, these fossil fuel technologies would be used sparingly, if at all. However, there are logical reasons they continue to play a major role in power generation today.

Technology	g CO_2e/kWh
Hydropower	7
Ocean power	8
Wind	10
Nuclear power	13
Concentrating solar power	20
Biopower	35
Solar photovoltaics	40
Geothermal	50
Natural gas combined cycle (NGCC)	450
Natural gas-fired combustion turbines (NGCT)	670
Coal	1000

Approximations are based on either ***Published*** *or* ***Harmonized*** *data. g=gram;* CO_2e *= carbon dioxide equivalent; kWh=kilowatt hour*

Figure 1-1. Life cycle analysis: comparison of select energy technologies

In a separate study NREL considered the capacity factor of different energy technologies. This is the amount of energy it produces over time divided by the amount of energy the technology could produce if its system were at full capacity.

The study shows coal has the highest range of capacity factors along with nuclear, geothermal, and biopower. They operate at more than 80 percent, making it easy for them to produce the base load (minimum level of demand) for electricity on the grid. Natural gas and hydropower have the widest range of capacity factors. In fact, natural gas-fired combustion turbines (NGCT) can operate between 10 and 90 percent. So even though it's one of the dirtiest technologies, it's the best match we have today for "marginal plants," which produce power swiftly to meet the grid's peak energy needs. While wind and solar are cleaner technologies, they have the lowest range of capacity factors. They are subject to varying weather conditions and the earth's rotation, and rarely operate beyond 50 percent.

Knowing the pros and cons of these technologies and feeling increased public scrutiny of its contribution to climate change, the power industry signaled its interest in greater innovation over the past few decades. The market responded favorably. New technologies arose that enabled utilities to moderately reduce emissions tied to coal and natural gas–generated electricity. More importantly, utilities diversified into cleaner, renewable energy as those technologies became more feasible and affordable. Those advancements also led to a proliferation of solutions in the market to help end users generate their own renewable power.

One such solution is solar energy. According the U.S. Department of Energy, Home Depot, one of the leading home improvement retailers in North America, only began selling residential solar power systems in its stores in 2001. Prior to that, the cost and performance of this technology did not make solar an attractive option for mainstream customers. Since then, the technology has become more efficient, cheaper to produce, and much less expensive to install.

Today, you can contact a turn-key company, like Solar City, to install, monitor, and maintain solar photovoltaic (PV) panels for your home or business. They will also finance them for you and share any savings that come from reducing the electric bill from your utility. This has become such a viable option for customers that by the end of 2014, nearly 645,000 US homes and businesses had chosen to go solar, according to the Solar Energy Industry Association.

Advancements like these give life to smart energy. They empower everyone to participate in the market contributing to a sufficient, reliable supply of electricity through more choice, greater efficiency, lower cost, and increased sustainability. The latest clean energy technologies deliver on this vision in spades, especially when paired with IoT-enabled solutions. Even so, more opportunity remains.

Without viable energy storage options, all electricity has to be used when it's produced. This limits the role that clean energy technologies, like solar and wind, can play in the overall power portfolio. Because they produce energy intermittently, they have less capacity to generate electricity just as it's needed. The absence of energy storage also prevents producers and customers from realizing additional cost savings and efficiencies. Storage is the last piece in the smart energy puzzle. Fortunately, breakthroughs in technology are making energy storage more feasible than ever and paving the way for mainstream adoption.

CHAPTER 2

Energy Storage: It's About Time

A major challenge facing any energy producer is finding a way to provide power when it's needed. Here's the dilemma for electricity. Demand varies. It's rarely in sync with the supply that can be generated by a single technology. Traditionally, producers align supply with demand by using a combination of technologies—some constant, some variable. While this has proven successful, meeting peak demand in this way drives up cost for producers and price for customers. It also creates an overreliance on fossil fuel.

"The electric power industry is built on the assumption that electricity cannot be stored and has to be generated exactly according to demand," said Randy Perretta. Perretta is owner of RP Consulting, a life cycle design firm for new products, and a journeyman in the energy industry. Reflecting on this conventional approach to syncing supply and demand, he shared, "Energy storage turns that assumption on its ear."

Smart energy storage solutions help solve the gap in timing between supply and demand. They enable producers to generate excess energy when demand is low, bank it, and then draw from the stored power supply when demand rises again. There are several types of energy storage solutions, but it is the latest generation of batteries that are making storage a much more affordable, feasible option for consumers, businesses, and utilities alike.

Patterns of Use and Production

Under normal circumstances, demand for electricity follows a fairly predictable cycle. As you might expect, it tracks with our natural biorhythms. When most of us are asleep, demand is low. Demand is higher when most of us are at home—waking up and getting ready for the day and again in the evening after work.

This correlation can be seen in Figure 2-1. The solid black line displays the circadian rhythm for an average person who tends to wake at 6:00 AM and go to sleep at 10:00 PM. It moves between opposing forces—the propensity to be awake or asleep. The dashed lines show a snapshot of three weekdays during January in 2013. They show hourly electricity demand tracked by PJM Interconnection, an organization that coordinates movement of wholesale electricity in more than a dozen states in the Atlantic and East Central regions of the US.

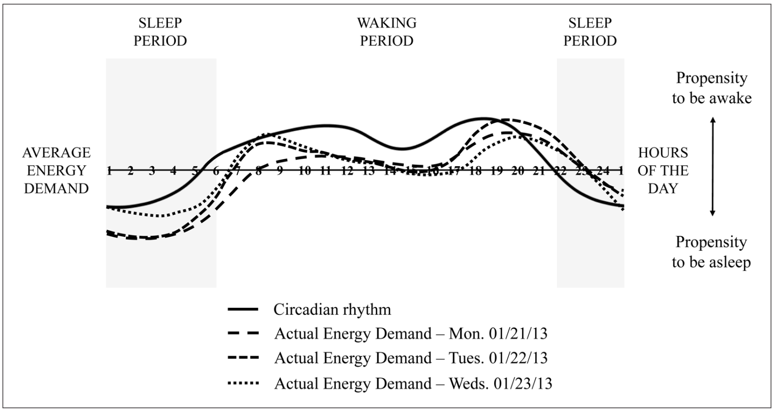


Figure 2-1. Circadian rhythm compared to actual energy demand

Here are the challenges that this variable demand poses to energy production technologies with two different profiles:

Constant, predictable supplies of electricity
: This includes fossil fuel technologies like coal and natural gas combined cycles (NGCC). It also includes some clean and/or renewable energies like nuclear, hydropower, geothermal, and biopower. As long as you feed them, these technologies can produce electricity round-the-clock with high predictability.

The primary challenge with this category is optimization. The best return on investment and lowest cost comes from constantly running these technologies near full capacity. However, if they consistently produced at the peak demand level, more electricity would be generated than the grid could accommodate when demand drops, especially at night and midday. That's why most are built to deliver the minimum demand for electricity, or base-load energy.

To meet additional demand, expected or otherwise, utilities rely on "peaker plants," usually natural-gas fired combustion turbines (NGCT). These flexible technologies produce a variable supply of electricity at a lower marginal cost. However, they're also among the heaviest energy polluters. Could we remove the need for peaker plants? Yes, if there was a way to stash the excess energy generated by the aforementioned technologies.

Variable, intermittent supplies of electricity

This includes wind, concentrating solar power, and solar PV technologies. Essentially limitless sources of power, these clean energy technologies can be used nearly anywhere on the planet and have some of lightest energy footprints. Nevertheless, their challenge is delivering energy with constancy.

Solar is available when the sun is shining. It hits peak energy production near midday as demand tends to dip. Production can be diminished by clouds and generates next to nothing as the earth rotates away from the sun each night. Wind can produce power any time of the day, but not with predictability because air flow varies from moment to moment.

This inconsistency in timing and the level of production usually prevents these renewable power sources from providing base load energy. Even though many end users are drawn to these increasing affordable technologies for on-site generation of marginal power, utilities tend to prefer NGCT peaker plants because they can generate power on-demand. Solar and wind technologies would become more viable options, if only they could store excess energy when their production exceeds demand.

Improving the Equation for All

Energy storage improves the equation for both power technology profiles mentioned above (constant, predictable supplies, and variable, intermittent supplies). It also enables producers, big and small, to capture excess energy when the power generated outpaces demand. That stored energy can then be tapped as needed when demand exceeds the supply of power being generated.

As long as the storage option is affordable, scalable, and easy to charge and discharge without significant energy loss, it can improve operational cost and efficiency for big producers like utilities that use constant, predictable energy technologies. Traditionally, their plants have been undersized in order to meet minimum electricity demand. With storage in place, these plants can be right-sized to generate power at a level closer to average demand, saving enough energy during dips in demand to meet the peaks.

It also helps right-size the overall cost structure for utilities by reducing reliance on peaker plants. By combining energy storage with primary energy technologies that produce a constant, predictable supply of power, it relegates peaker plants to a backup role. Much like a diesel generator for your home, a peaker plant is great for generating electricity on demand. However, both are much more expensive to operate per kilowatt hour (kWh) than main power sources. They are best used for rare, unexpected circumstances when main power source failures outlast stored energy supplies. Reducing reliance on peaker plants would also benefit the environment, under all circumstances except when the alternative is coal.

The good news is that energy storage also opens up a path for minimizing, or even phasing out, the use of fossil fuels. Variable, intermittent energy technologies like solar and wind can also be ramped up to ride out the peaks and valleys of demand when combined with energy storage. The algorithms for charging and discharging electrons to and from storage using this technology to meet average demand will differ from their constant, predictable counterparts. However, in some locations, this ability to bank energy now enables solar and wind to compete with fossil fuels for primary power production for the first time. The question is no longer, “Which energy technology is capable of meeting demand?” It becomes, “Which technologies are best adapted to producing electricity in a particular location based on the area's natural resources and their impact to climate change?"

Energy storage is equally beneficial for end users and small producers. Today, because of the higher cost of meeting marginal energy demand, utilities charge end users a premium price for electricity used during "on-peak" hours. For example, in 2015 Florida Power & Light charged customers a higher rate per kWh from November 1st to March 31st on Monday through Friday between 6–10 AM and 6–10 PM, and from April 1st to October 31st on Monday through Friday between 12–9 PM (excluding major holidays throughout the year). Energy storage would enable Florida Power & Light's end users to purchase excess energy in "off-peak" hours, when the price per kWh is lower. They could then draw from that reserve to reduce reliance on the electric grid when rates rise during "on-peak" hours like those just mentioned.

The benefits are even more enticing when end users become small producers—generating some of their own electricity through renewable energy technologies on site. Many government programs offer economic incentives and financing options to help them reduce or spread out the cost of buying and installing on-site systems. Also, through a policy called "net metering," they can send some of the excess renewable energy generated back to the grid in exchange for a 1:1 kWh credit. This system of credits has been adopted in various forms around the world. As of September 2015, it was available in all but four states in the US, according to the DSIRE database operated by the N.C. Clean Energy Technology Center at North Carolina State University and funded by the U.S. Department of Energy.

To take advantage of these credits, these small producers must have a smart meter installed on their premises by the local utility to gauge the usage and directional flow of energy at any time of day. States regulate how much energy the utility's end users (subscribers) can contribute to the grid through their small production, which prevents the grid from being overloaded. Together, subscribers may be limited to contributing no more than a certain percent of a utility's historical peak load. This can range from 0.1 percent of the load to unlimited contributions depending on the state. Individually, subscribers also may be capped on how much power their system can produce or how much credit they receive for energy they net meter back to the grid. Among the states, system capacity limits range vastly from 10 to 80,000 kilowatts (kW). One of the most progressive states, Arizona, only caps net metering credits at 125 percent of a subscriber's load.

With all of this mind, it's clear to see how energy storage can be a game changer. Big producers can use it to build an infrastructure that meets demand while reducing reliance on peaker plants, operating at lower cost and integrating cleaner energy technology. End users, at the very least, can use it for backup power or storing low-cost energy to use when electricity prices are higher. End users, who become small producers, can also use it to store any excess renewable energy generated on-site. With all these benefits, that just leaves one key question. What options exist for storing energy?

Energy Storage Options

Utilities have deployed a variety of technologies to store excess energy over the years. They range from the use of gravity and angular momentum to compression and thermal absorption. One method widely adopted by utilities is using some of the energy they generate during off-peak hours to pump water uphill to a storage facility. This essentially converts kinetic energy (the pumping) to potential energy (the stored water). When demand rises and more power is required, the water is released downhill. Gravity helps convert the water's potential energy back into the kinetic energy used to spin the turbines below and generate electricity.

Turbines can also be propelled by using stored, compressed air. One example is Highview Power. Using its technology, a producer can use off-peak electricity to cool air down to –196°C, turning it into a liquid. This highly compressed air is then stored in large-scale, insulated, unpressurized vessels. When energy demand increases, this stored supply can be accessed by opening a valve. As it's exposed to ambient temperatures, the air rapidly re-gasifies. Its volume expands 700-fold, driving a turbine to create electricity.

Another mechanical solution is the use of flywheels. Here's how it works. Off-peak energy can be used to power motors that start flywheels in motion. These flywheels, or rotors, spin in a nearly frictionless enclosure supported by magnetic levitation. Their angular momentum (or continuous rotation) stores energy, which can be drawn back out through the motor converting it into an electric generator.

Thermal storage solutions can also be effective. For example, Abengoa Solar has built a 280-megawatt solar plant southwest of Phoenix, Arizona. It uses parabolic mirror troughs to concentrate the sun's rays on oil that is piped through them. As the oil heats up, its thermal energy is used to boil water, creating the steam to spin electric generating turbines. When the plant is running at capacity, the oil's heat is transferred to molten salts until it's needed again. This solution stores enough heat to run the plant's turbines at full capacity for six hours.

All of these solutions work on a utility-scale. However, it's unlikely that they can be replicated at a scale and price that would work for small to mid-size businesses and consumers. The substantial cost associated with building and operating these storage solutions has likely limited adoption by utilities, as well. Only 16 percent of utilities surveyed in Black & Veatch's 2014 Strategic Directions: U.S. Electric Industry Report were requiring energy storage for variable generation projects or running an energy storage pilot project. Even so, advancements in another energy storage technology—batteries—are accelerating adoption in the market.

While storing energy in batteries is nothing new, battery technology is undergoing a significant transformation. Lead-acid batteries have been used to store backup power by utilities, businesses, and consumers for years. They are effective at storing and discharging energy in large-scale scenarios such as utility substations and corporate data centers, even in small-scale deployments for homeowners. However, the challenge is regularly tapping that energy. In general, lead-acid batteries can only be deep-cycled—discharging most of the energy in their reservoir—a few times in their life. While this is sufficient for occasional backup use, it limits their ability to cost-effectively address the daily demand of peak energy.

When unveiling the Tesla Powerwall—a battery based on lithium iron phosphate (LiFePO4) chemistry—the company's CEO, Elon Musk, shared a much less generous assessment: "The issue with existing batteries is that they suck." Behind him on the stage was a presentation slide listing their downsides: expensive, unreliable, poor integration, poor lifetime, low efficiency, not scalable, and unattractive.

That describes, in a nutshell, why lithium-ion batteries have a leg up on lead-acid batteries. They can discharge deeply with near-constant voltage, enabling these batteries to essentially deliver full power until they are nearly spent—something their lead-acid and even nickel-based counterparts are unable to do. LiFePO4 batteries have a longer lifespan. They are significantly lighter in weight. They can also be charged much more quickly and efficiently. This enables them to carry a supply of energy that can be accessed much more often, even if they are not fully charged. Until recently, the main challenge facing the lithium-ion battery industry has been producing them at a price that makes them affordable for the mass market.

Fortunately, those costs are falling. According to a study published in *Nature Climate Change*, industry-wide cost estimates for producing lithium-ion battery packs for battery electric vehicles (BEV) dropped approximately 14 percent per year between 2007 and 2014 —from above $1,000/kWh to near $410/kWh. The cost of battery packs used by market-leading BEV manufacturers, Nissan Motors for the Leaf and Tesla Motors for the Model S, are lower—$300/kWh. This cost advantage, now and in the future, is one of the prime reasons Tesla is poised to lead the development of mobile *and* stationary energy storage for years to come.

CHAPTER 3

Enter Tesla

In the spring of 2015, Tesla made a splash by officially announcing its entrance into the stationary energy storage market. It introduced the Powerwall and its big brother, the Powerpack—rechargeable lithium-ion battery solutions that can meet storage needs large and small. Interestingly, according to Q2 2015 report of the U.S. Energy Storage Monitor published by GTM Research, there were at least two dozen energy storage system vendors operating in the US marketplace at the time. Considering the healthy competition already in this space, why would a car manufacturer throw its hat in the ring?

"Tesla already knows how to do this. They've been putting LiFePO4 batteries in their cars for years. They have the experience," said Randy Perretta. By 2014, Tesla and its supplier, Panasonic Corporation, were already producing enough lithium-ion battery packs to outfit each of the approximately 35,000 vehicles it manufactured that year. The technology, materials, and know-how necessary to develop a stationary energy solution are so similar that Tesla is banking on economies of scale to drive down the cost of production for car and facility batteries alike as its production ramps up.

Another advantage Tesla had upon entering this market was an established customer base. Tens of thousands of customers own Tesla Roadster and Model S electric vehicles (EVs). It's likely many of them are interested in charging those EVs at home using renewable energy. A 2015 PlugInsights survey of EV drivers located primarily in the US confirms that assumption. In it, 83 percent said they had solar panels at home already or would consider installing them in order to get a true zero-emission driving experience. Because EVs are usually charged at night and solar energy is generated during the day, a charging station alone isn't enough. It also requires an energy storage solution like the Powerwall to help owners store energy from the sun for use when the moon is shining.

What Is the Powerwall?

The Tesla Powerwall is a wall-mounted rechargeable lithium-ion battery designed to help homeowners or small business owners to store energy. It includes a battery pack, liquid thermal control system, and software that receives dispatch commands from a solar inverter. The Powerwall is about the size of a 60-inch flat-screen TV (if it was hung portrait style), and weighs 220 lbs. Unlike competitors, which tend to emphasize function over form, the Powerwall's sleekly sculptured form is Apple-esque, making seem it more like a luxurious piece of art on the wall (Figure 3-1).

The Powerwall takes two forms. The 10 kWh weekly cycle model is $3,500 and designed to provide backup power. The 7 kWh daily cycle model has a $3,000 price point and is designed for load shifting—charging when electricity demand and rates are lower and discharging when electricity demand and rates are higher. Both come with a 10-year guarantee and are sufficient to power most homes during peak evening hours by delivering 2 kW of continuous power and as much as 3.3 kW of peak power. The Powerwall is also modular. If your home or business needs more energy, multiple units can be installed together—achieving up to 90 kWh total for the 10 kWh battery and 63 kWh total for the 7 kWh battery.

Figure 3-1. Tesla Powerwall

Powerwall's Partner—The Smart Inverter

To unlock the Powerwall's potential, you'll need to pair it with a smart inverter from one of Tesla's approved partners. Figure 3-2 provides an example of what this looks like for a consumer whose home has solar PV panels and is linked to the electric grid. The solar panels are connected on one side of the inverter and feed direct current (DC) into it. The Powerwall is wired to the inverter on that same side through a separate connection that enables DC power to flow back and forth. On the other side of the inverter is a connection to the control panel (the gateway to all electrical wiring inside the home), followed by a connection to the utility's smart meter, and followed last by a connection to the grid. All of the wiring between the inverter and the grid carries alternating current (AC).

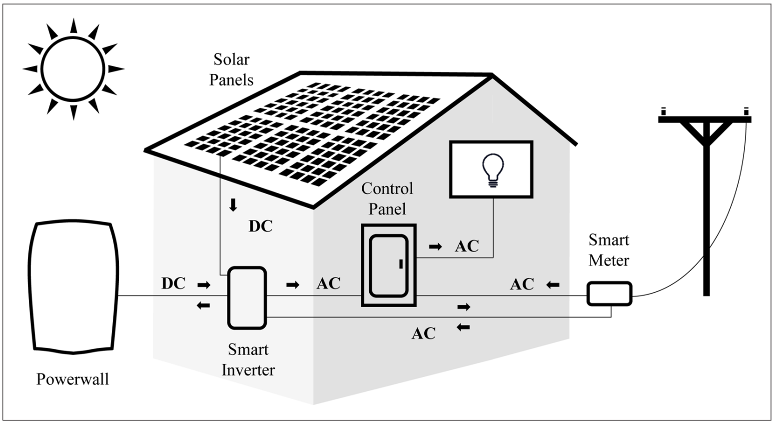


Figure 3-2. Electrical network for residence with solar and power storage

The inverter has two primary jobs. First, it converts power from DC to AC and back as needed within the home's network. Using transformers and circuits, it can convert DC energy, generated by the solar panels or stored in the Powerwall, into the AC electricity required to power the home's appliances or for net metering contributions to the grid. Because the inverter is bi-directional, it can also take AC power flowing from the grid and turn it into DC energy for Powerwall storage.

Second, the inverter acts like a traffic cop. It connects to the Internet and cloud-based applications with algorithms to determine where power should flow within the home network and at what pace. It's a continuous balancing act—analyzing the home's energy demands, how much power the solar panels are contributing, what grid electricity currently costs per kWh, how much energy is stored in the Powerwall, and at what rate the battery should be charged or discharged.

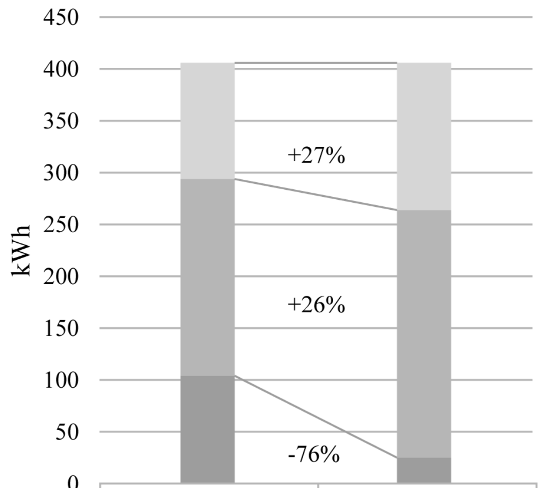
The inverter seeks to optimize the system so the homeowner uses as much solar power as possible, draws from the grid when electricity is cheap, and contributes excess energy to the grid to maximize net metering credits. Typically, the user can monitor this performance through a web-based dashboard. It displays ongoing details of energy production, use, storage, and cost in addition to how well the inverter, solar panels, and Powerwall are operating.

Consumer Benefits

The easiest way to understand the Powerwall's potential is by viewing it through a real-life example. To illustrate the benefits a homeowner could experience by installing Tesla's 7 kW energy storage system, we'll look at house located on the gulf coast of Florida in Sarasota County. This 3-bedroom, 2-bath home with 2,000 square feet already has a solar system installed. The rooftop system includes 22 PV panels with a total power-generating capacity of 5.5 kW. The homeowner currently has a net metering arrangement with the local utility, but no energy storage system.

Figure 3-3 highlights energy used during one week of the summer—August 8–14, 2015. The left column represents the actual use and energy sources. As you can see, even without the Powerwall in place, the homeowner is already saving money by producing more than a quarter of the energy used by the home (112 kWh) from solar. The rest is being purchased from the local utility during off-peak hours —9 PM–Noon (190 kWh) at a lower price, or on-peak hours—Noon–9PM (104 kWh) at a higher price. Because there is no power storage system on-site, the homeowner is unable to use the excess solar energy generated and net meters 30 kWh back to the grid.

The righthand column in Figure 3-3 shows the potential that the Powerwall has to further increase the homeowner's savings. To begin, let's take that 30 kWh of excess solar energy and store it in the Powerwall, rather than net metering it back to the grid. With that power stored, it can be used during on-peak hours reducing the home's grid-energy demand when prices are highest. For the sake of simplicity, let's also assume that each evening the homeowner fully charges the Powerwall during off-peak hours and discharges it during the next on-peak period. That would shift a total of 49 kWh (7 kWh/day times 7 days). The result is impressive—a 27 percent increase in solar energy used, a 26 percent increase in off-peak energy used, and a 76% decrease in on-peak energy used. Over time, this shift away from on-peak demand will generate a significant return on investment.



	Without Powerwall	Potential with Powerwall
Solar	**112**	**142**
Direct	112	112
Stored	0	30
Grid Off-peak	**190**	**239**
Direct	190	190
Stored	0	49
Grid On-peak	**104**	**25**
Total	**406**	**406**
Net-metered Solar to Grid	30	0

Figure 3-3. Florida Gulf Coast home with 5.5 Kw rooftop solar system: energy used week of Aug 8–14, 2015

Enterprise Adoption

What if your storage needs go beyond that of a homeowner or small retail store? Tesla's answer is the Powerpack—an industrial version of the Powerwall. It has much more storage capacity, 100 kWh, and in Elon Musk's words, "is infinitely scalable." Also according to Musk it costs around $250 per kWh, a price tag of apparently $25,000. Using a cabinet and rack system, Powerpack units can be combined to achieve up to 500 kWh per cabinet. Cabinets then can be connected to create up to 10 megawatt hours (MWh) of capacity. This product can support a wide range of customers from mid-size businesses to large-scale operations like utilities, data centers, and manufacturing plants.

From the vantage point of CBRE, the world's largest commercial real estate services firm, energy storage is still early in the technology adoption cycle for businesses. Vice President Elodie Geoffroy-Michaels oversees Global Energy and Sustainability for CBRE's Global Corporate Services division. When asked whether energy storage fits into the sustainability strategy CBRE recommends for its clients, she said, "Yes, but this is in its infancy stage. There is little demand for this product yet." Even so, Geoffroy-Michaels stated CBRE does recommend energy storage to clients, primarily to help them curtail costs associated with peak demand and as backup power for business continuity.

While other companies consider whether and how to integrate power storage into their energy plans, Jackson Family Wines (JFW) and Amazon are already ahead of the curve. Both have deployed Tesla's stationary energy storage solution. JFW has been piloting a prototype of the Tesla Powerpack to help reduce energy use in four areas that consume the most electricity in their winemaking operations: refrigeration/cooling, lighting, compressed air, and process water treatment. Each battery pack is designed to draw electricity from the grid or their on-site solar arrays when energy demand is low. The power is stored for later to smooth out spikes in demand. "We're anticipating a 10 percent reduction in our annual electricity bills as a result mostly of demand shaving," said Julien Gervreau, Senior Sustainability Manager for JFW.

Amazon Web Services (AWS), which provides data center services to startups, large enterprises, and government agencies in 190 countries, has a long-term goal to become carbon-neutral by using 100 percent renewable energy. To that end, in the spring of 2015, AWS announced plans to launch a 4.8 MWh hour pilot of Tesla's Powerpacks in its US West Region. "Batteries are important for both data center reliability and as enablers for the efficient application of renewable power. They help bridge the gap between intermittent production, from sources like wind, and the data center's constant power demands," said James Hamilton, Distinguished Engineer at AWS. "This complements our strategy to use renewable energy to power our global infrastructure."

There are two signs that the adoption rate for this technology is about to pick up. First, the utilities see the wave coming. In its 2015 Strategic Directions: U.S. Electric Industry Report, the Black & Veatch Insights Group asked them the following question: “As demand response becomes more of an operation resource to utilities, what emerging trends do you see impacting your business?” In the top response, 62 percent of utilities said “renewables combined with battery storage.” Second, consider the response to Tesla’s introduction of the Powerwall and Powerpack. Just three months after the unveiling, during Tesla’s 2Q15 earnings call, CEO Musk and CTO JB Straubel announced they had received orders for 100,000 of these energy storage products with a total value of about $1 billion.

Why Tesla Is a Game Changer

So what’s the big deal? Tesla wasn’t the first company to introduce a stationary energy storage system for homeowners. Enphase, one of the largest manufacturers and distributors of solar inverters in the world, announced its development and testing of a residential model six months before Tesla introduced the Powerwall. Also, companies like Stem have been selling energy storage solutions paired with robust cloud-based software for data analysis and predictions to companies for a few years now. So why is it that neither has commanded the same media attention or order demand experienced by Tesla?

“Tesla is part of the American fabric, and they’re led by a fellow who sees to the horizon,” said Randy Perretta. “Having Elon Musk in the game is big. Society sees him as a person lighting the way already. If he points down a path, society and business will follow, because they believe in him.” As founder of SpaceX and a cofounder PayPal and Tesla Motors, Musk has frequently captured the public’s imagination with his vision of the future and fulfilled it. In doing so, he and his products attract the sort of adulation once reserved for the late Steve Jobs and the unveiling of Apple products like the iPhone.

Much like the iPhone, the Powerwall’s design is stylish, warm, and inviting. It’s easy to imagine how nice it would look inside your garage next to your Model S. This visual appeal opens it up to the mainstream market. Also like the original iPhone, the Powerwall is just a stake in the ground. Its storage capacity, amperage, and price can all be significantly improved, yet Musk sees this as an opportunity to whet the public's appetite with an initial offering. Just as the original iPhone now seems quaint and archaic compared to the iPhone 6S, released less than a decade later, the original Powerwall is destined to be antiquated just as quickly.

That fate will be delivered by Tesla's own hand via the "Gigafactory" —a massive battery factory that will have a production capacity of 35 gigawatt-hours (GWh). Tesla, Panasonic, and other strategic partners, broke ground on this manufacturing plant in June 2014 just outside Sparks, Nevada. They are investing $4.5 billion to make it a reality. The plans are to have it built and launch production through the plant in 2017. By 2020, the Gigafactory will reach full capacity and produce more lithium-ion batteries annually than were produced worldwide in 2013.

The sheer manufacturing capacity of this plant along with rapid growth in demand for EV batteries and stationary batteries (like the Powerwall and Powerpack) will enable Tesla to leverage significant economies of scale. Based on some estimates, Tesla believes it can drive down the per kWh cost of its battery pack by more than 30 percent. Production on this scale will also help fund additional research into increasing the energy density and lifespan of the batteries. Higher performance, lower cost, and increased competition that will come as a result (all of Tesla's patents are open source), will help drive mass adoption of energy storage. It's when this technology becomes ubiquitous that things get very interesting.

CHAPTER 4
Looking Ahead

The market is undergoing an exciting transformation toward smart energy. As we've seen, a key change is the transition away from electricity that relies heavily on fossil fuels—a limited resource that contributes heavily to climate change. Thanks to advances in technology, it's now viable for utilities, businesses, and homeowners to produce clean, renewable energy en masse. Solutions like Tesla's Powerwall and Powerpack take this to the next level. By storing excess energy produced by intermittent sources like solar and wind, they help smooth out supply and align it with demand. Together, these innovations enable renewable energy, once a niche player, to take on a major role in energy production.

The other critical ingredient for smart energy is the ability to glean and share information throughout the market with swiftness and ease. IoT-based solutions are doing just that. Connected devices like learning thermostats and intelligent lighting systems are helping us curb our demand for electricity. They recognize when we really need it then dispatch it accordingly. Smart meters and inverters are helping us to understand demand in real time and whether to draw energy locally (e.g., from solar panels or battery storage at home) or from the grid based on timing, supply, and cost. Solutions like WattTime can even help us to optimize our environmental footprint by sourcing electricity from the grid when the cleanest choices for marginal energy are online.

What we're beginning to see is a profound reshaping of the marketplace. Energy production is becoming decentralized. With each passing day, more of us are able to produce and store electricity affordably on our own. In addition, the Internet has made us more aware of the demand that exists and what supplies are available to meet it from moment-to-moment. This is the dawn of what futurist and economist Jeremy Rifkin refers to as the "energy internet" in his bestselling book, *The Third Industrial Revolution*.

In his book, Rifkin asks us to imagine "hundreds of millions of people producing their own green energy in their homes, offices and factories, and sharing it with each other in an energy internet, just like we now create and share information online." This evolution redefines what it means to be a producer and consumer. Those roles are no longer black and white. It blurs the lines. However, it enables new peer-to-peer business models to emerge that improve efficiency and cost.

Think of successful startups like Uber, where just about anyone with a car and some free time can supply a ride for someone needing a lift, or the Lending Club, where individuals can pool their money with others to easily offer interest-bearing loans to peers who want to buy a car or pay off a credit card. These epitomize a "sharing economy" where people and organizations use information technology to determine demand, evaluate their excess capacity, and then redistribute, share, and reuse it for optimal benefit. That infrastructure is beginning to emerge for energy. It's exciting to ponder what lies ahead for developers of cloud-based solutions, IoT devices, and big data analytics as regulations in the energy market begin to relax. Following are a few examples of future opportunities.

Open Meets Local

Besides being attractive, user-friendly, and one of the lowest cost lithium-ion solutions for stationary storage on the market per kWh, Tesla's Powerwall and Powerpack are unique for another reason. Like all Tesla technology, their patents are "open source." CEO Musk has stated, "Tesla will not initiate patent lawsuits against anyone who, in good faith, wants to use our technology." In his blog announcing this decision, he notes that Tesla, the competition, and the world would all benefit from a common, rapidly evolving technology platform.

Randy Perretta sees that potential, as well. "Open source and local management are a marriage made in heaven," he said. Consider the transition to micro-grids—small energy systems capable of maintaining a balance between energy supply and demand within a defined boundary. Many predict this to naturally arise from the mass decentralization of electricity production. If so, Perretta envisions, “By having free standard software interfaces and reusable code with public access, software developers can and will economically provide products to the micro-grids and individual customers which allow them to better manage this resource and discover new ways to avail themselves of it.”

This opens the door to greater awareness of what’s happening at the street level, the building level, and even down to the local environment where equipment like the inverter lives. With that awareness also comes an opportunity for greater local management. Perretta muses, “The day when local (energy) storage/generation management becomes seamless with building HVAC management, climate data and financial date will be a breakout moment.”

As an example, he points to three-phase motor starts in inverters. Three different voltages are applied to these motors all at once to get them spinning at full speed. Because the motors begin at rest, the initial current is much higher than full load to get them moving. These “hard starts” cause wear and tear on motors. However, when sudden unexpected power surges occur, they really take a toll. As Perretta notes, “A power pole in the alley can absorb the current hit of electricity without even noticing it. Utilities put switchable capacitor banks on the pole to offset the power factor issues. However, to an inverter on a wall in an electrical closet, a number of three-phase motor starts can seem like being hit by a cannon shell.”

Enterprising developers can create software and algorithms and deploy wireless sensors to proactively monitor this impact. “Suppose we watch that from day to day?” Perretta said. “For instance, motor starts happen on a regular schedule. As time goes on and one of the motors begins to fail, it starts harder. The change in building current and power factor over those few seconds every day as the motor fails can get noticed. With this local building profile analysis, you can replace or repair the motor before it fails.” As a result, it saves downtime and enables the local energy storage and generation equipment to stay online. Otherwise, the system would revert to the grid to satisfy its energy needs, incurring a higher cost for electricity during peak periods of the day.

Micro Virtual Utilities

Someday, in the not-so-distant future, landlords of multitenant properties may find it financially attractive to act as micro virtual utilities. Because they control the flow of electricity into the commercial and housing units they lease, they also have the ability to enhance that service through the use of energy storage and any renewable energy produced on-site. Landlords could operate like mini-utilities, providing tenants with power that they've purchased and resold from the grid and/or power that they've generated themselves. The only electric bill the tenant would receive is the monthly invoice from their landlord.

Here's how it could work with energy storage alone. The 7 kWh Tesla Powerwall can provide adequate energy storage for the average home. Because Powerwalls are modular, a landlord with a handful of adjoined properties could just purchase a few and link them together. A Powerpack would be best for landlords with larger multitenant properties. With an energy storage solution in place, they could then buy cheap energy from the utility during off-peak hours, store it, and provide the stored energy to tenants during peak hours when utilities charge the most for electricity. When reselling the energy during peak hours, the landlord could even charge less than the utility, because there's often a sizeable margin between peak and off-peak rates. This would benefit both parties—tenants would pay less than the market rate while landlords would still make a nice profit.

The "buy low, sell high" approach also works well when on-site solar, wind, and even biopower are introduced into the mix. Landlords can profit by continuing to sell their own energy to tenants during peak periods, even after their stored energy supplies have run out. Renewable energy also adds two other financial benefits. First, it enables landlords to get PACE financing for the purchase and installation of the power generation and storage equipment. This can spread the payment out over decades, substantially lowering upfront cost. Second, it enables landlords to more easily secure LEED certification for a building. That's a plus, since the U.S. Green Building Council shows that vacancy rates for green buildings run slightly lower than for nongreen properties and LEED-certified buildings continue to command the highest rents.

The key to making this work is an IoT-based billing platform. The solution would rely on a centralized smart inverter to guide the flow of energy from the on-site renewable source or the electric grid, to and from the Powerwall or Powerpacks, and to the tenants. A smart meter would be installed for each tenant. It would sense local demand, communicate it to the inverter, and track energy use. All of this data would be conveyed back to a cloud-based software system that, among other things, would assign the appropriate billing rate per kWh based on time of use and provide the landlord with an administrative dashboard to monitor all energy use throughout the property and the health of the overall system. It would even offer tenants a web page—just like the local utility does—where they can check their energy use, view their bill, and make payments to the landlord online.

Distributed Storage Network

As more consumers and businesses install energy storage systems in their homes and facilities, it's intriguing to consider the collective impact. Most will likely stay connected to the electric grid, at least for backup power. Together, all of those connections represent a vast network of distributed storage. If utilities could control most or some of that resource, it could help them meet peak energy needs for all customers while reducing their expenses for infrastructure and operations. It could also generate financial discounts, incentives, or income for businesses and homeowners who allow the utilities to tap into their stored energy supplies.

This strategy is similar to the demand-shaving programs many utilities already have in place. They offer intelligent, programmable thermostats and installation to customers at little or no cost. In return, customers voluntarily allow the utilities to adjust indoor temperature higher or lower, depending on the season, to reduce overall demand during periods of peak demand. The utilities benefit by not having to fire up their peaker plants as much, which cost more to run than their base-load operations. Customers benefit by receiving new thermostats. They can program these devices to stay at set temperatures at different times around the clock, curbing energy use and lowering their electric bill.

Instead of focusing on demand, a voluntary program for shared energy storage would address the supply side of the equation. Utilities could offer substantial discounts or leasing arrangements to customers who want to acquire and install energy storage systems and smart inverters. If customers already have approved equipment in place, the utilities could offer them energy credits or compensation. All of this would be in exchange for allowing the utility to tap into the customer's reservoir of stored energy, within certain parameters agreed upon in advance.

The benefit for utilities is two-fold. First, they can avoid the cost of building, maintaining, and operating their own centralized storage facility. Most of this cost for energy storage is shifted to customers in the network or an approved partner, like Solar City, that provides, installs, and finances the equipment for customers. Second, utilities can reduce their use of peaker plants even further—potentially decommissioning plants as the capacity and reliability of the distributed energy storage network becomes sufficient. Customers benefit by receiving equipment subsidized by the utilities and from credits or income generated by each stored kWh they contribute back to the grid.

All of these benefits can be realized only if there's an IoT-based solution in place. It requires sensors distributed throughout the network to monitor energy storage levels and demand—at a micro and macro level. It also requires a cloud-based software system that can assess demand and supply, then draw just the right amount of energy from each of these reserves without overloading the grid.

Toll-Based Energy Highways

With the rise of individual energy producers—businesses and homeowners who generate and store their own power—will eventually come the trading and selling of their excess electricity. In time, this collective supply of individually produced energy may become so large and well-networked that utilities may decide to scale back their energy production and diversify into other areas of business.

Utilities have a deep understanding of how to finance, produce, and distribute energy; forecast and meet market demand; manage risk and respond to outages; bill and provide customer care for services; and more. In this new era, they may find it more lucrative to offer value-added services like the following to individual producers:

- Consultation on technology, operational efficiency, and risk
- Back-office services including customer care and invoicing
- An Uber-like platform for matching supply with demand
- Aggregation services that bundle supplies for large customers
- Brokerage services to help clients compete more effectively

Between now and then, one thing remains certain. There will be escalating tension over who pays for expanding, upgrading, and maintaining the grid that makes the distribution of electricity possible. Today, this cost is borne by the utilities. They currently produce the vast majority of energy available in the US. Therefore, they rely most on the electric grid to get that power out to their customers. That's as it should be. Those who benefit most from a system should carry the largest cost of supporting it. However, what happens when that balance begins to shift?

Individual producers contribute excess electricity to the grid today. While it's a relatively small amount compared to the whole, it's still been enough to give utilities pause for concern. This can be seen in the slow adoption of net metering over the years. As you'll recall, four states still do not support it. It's also apparent in the disparity of net metering rules between states. While some are encouraging, many still significantly limit how much energy individual producers may generate and the net metering credits received in return.

Utilities significantly influence these regulations. While they have a historical bias toward limiting competition, there's another primary reason utilities seek to slow this trend. They don't want to see their revenue siphoned off bit by bit while being left to hold the entire bag on funding the grid's infrastructure. In that light, it's easy to begin seeing individual producers as freeloaders. Unless a system is established for cost sharing, tensions will continue to rise as individual producers contribute a larger portion of the electricity in the grid.

Here's one way to solve for it. Develop a smart solution that emulates a toll road. Just as drivers pay for a minute portion of a highway's maintenance and upgrades each time they use the road, a system could be created to monitor energy flows into the electric grid from any producer and assess a toll based on that usage. A nominal fee paid per kWh would enable the grid's upkeep and improvements to be funded proportionally by those who rely on its use. Implementing this solution would require each gateway controlling the flow of energy into the grid to have a unique IP address associated with the producer. Internet-connected smart meters would track how much energy each contributes to the grid and communicate it to a centralized clearinghouse in the cloud. That party would bill each user on a pro rata basis. It could also use the data to project many things, including local areas where supply is increasing and the grid's capacity should be enhanced.

The Era of Smart Energy

As we've seen throughout this report, the energy space is undergoing an exciting evolution. Advancements in power generation technology have paved the way for cleaner production and empowered businesses and homeowners to produce their own electricity. The development of affordable power storage solutions, like the Tesla Powerwall, is accelerating adoption of these technologies, primarily solar and wind, by evening out their intermittent production. It is also enabling individual producers to contribute more of their own energy into the grid.

Lastly, these systems are now connected. Through the deployment of IoT-based sensors on-site and throughout the grid, we know much more about how energy is being produced, stored, sourced, traded, and used. Through this energy internet, we also have the smart devices, software, and analytics to optimize all of this data for maximum benefit, regardless of where one fits into the energy marketplace. This is giving rise to a range of new business models and rolling out the welcome mat for innovation. The era of Smart Energy has arrived.

About the Author

Darren Beck is a professional with more than 25 years of combined experience in business development, strategy, technology, sustainability, and shared value.

In addition to writing about green practices in IoT for O'Reilly Media, Darren serves as Director of Environmental Initiatives for Sprint where he has helped the company to gain recognition as the most eco-focused wireless carrier in the US. At Sprint, he is responsible for driving innovation that reduces environmental impact while enhancing the company's reputation and its bottom line.

Darren is also an Advisory Board Member for DaVinci Global, an organization designed to be the world's leading source of insights into nature-inspired design for innovation, business, and finance.

He holds an MBA from the University of Kansas and a Bachelor's of Science in Mass Communications and Business from Baker University. Follow him on Twitter *@DarrenBeck* for the latest news on sustainability, technology, and ideas for making the world a better place.