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Energy Storage

The Next Charge for Distributed Energy

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ILSR INSTITUTE FOR Local Self-Reliance

Executive Summary

Distributed energy storage promises to change the electricity system during the next decade, as fundamentally as distributed renewable energy has in the last decade.

Already, promising examples of local renewable energy combined with energy storage illustrate how the powerful combination can allow for more thorough adoption of renewable energy and support greater local control of the energy system.

Where Storage and Renewables Meet

Examples of energy storage that enhances distributed renewable energy include:

- Electric vehicles (EVs) – EVs provide an economical alternative to driving on petroleum fuel, and offer a broadly distributed method of storing grid electricity for future use.

*A 2011 study by the Pacific Northwest National Laboratories illustrated how **large-scale deployment of electric vehicles** in the seven-state Northwest Power Pool **could double the wind power on the regional grid system** by absorbing excess wind power production at times of low demand, adding 10 gigawatts.*

- Community solar – local solar projects can more effectively meet local energy demand and storage increases the potential scale of local solar projects.
- Island power grids – modeling remarkably high penetrations of variable renewable energy (40% and higher), island grid energy storage can maintain reliability and the match between supply and demand.
- Microgrids – localized power systems can reduce costs, increase reliability, and scale up renewables, made possible by combining local energy production and storage.

*With existing distributed solar projects and those in the pipeline, the **Kaua'i Island Utility Cooperative** plans to use distributed energy storage and solar to **meet half of the daytime energy** use on the island by the end of 2015.*

Energy Storage Technology and Uses

Over 95% of deployed energy storage is in the form of water stored in hydropower reservoirs. But new promising technologies are being commercialized to support distributed renewable energy and meet the reliability and quality needs of the electricity system.

Energy storage can serve a number of important roles on the electricity grid, much more than simply storing daytime solar electricity for nighttime use, for example.

Uses for energy storage include:

- Managing Supply and Demand – energy customers can reduce their bills by shifting energy use to low demand periods or by reducing their maximum energy use in a given month. Energy storage can cost-effectively supply capacity and backup power that has historically been provided by expensive quick-response fossil fuel power plants.
- Delivering Ancillary Services – at every moment supply and demand of electricity must be in balance. Energy storage can respond more quickly than most existing technologies, helping maintain the voltage and frequency of the electricity system to avoid damage to connected electronics and motors, and avoid power outages.
- Reinforcing Infrastructure – power lines, transformers and other grid infrastructure wears more quickly when operating at peak capacity. Energy storage can shift energy demand to ease stress on expensive equipment. It also allows energy users to manage their own energy use.
- Supporting Renewable Energy – renewables are often variable, and variable energy can be challenging for inflexible utility power plants to accommodate. Energy storage responds quickly and effectively to variations in renewable energy output, enabling higher penetrations of wind and solar on the electric grid.

Energy Storage

Medium	Technology
Chemical	Battery
	Fuel Cell
Thermal	Ice
	Water
	Molten salt
Potential	Hydro
	Rail car
	Compressed air
Kinetic	Flywheel
	Regenerative braking

Source: Institute for Local Self-Reliance

How Energy Storage Will Grow

Use of energy storage will continue to grow significantly, for three reasons:

1. Falling costs will permit utilities to more efficiently integrate high percentages of renewable energy;
2. Electric vehicle use will continue to grow quickly as a cost-effective alternative to petroleum fueled vehicles; and,
3. Businesses, individuals, and other entities will seek more control over their energy system, enabled by energy storage.

Energy storage will also change the political dynamic of local renewable energy development. Utilities that have tried erecting barriers to on-site power generation may find that cost-effective energy storage enables their customers to leave the grid. Although most will not leave, the option to defect (described in a recent Rocky Mountain Institute Report[1]) will give electricity customers unprecedented leverage and control over their energy future.

Energy storage stands at the cusp of major growth. Its adoption will accelerate the transformation toward a democratic energy system.

Acknowledgments

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—John Farrell, jfarrell@ilsr.org

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Table of Contents

Introduction

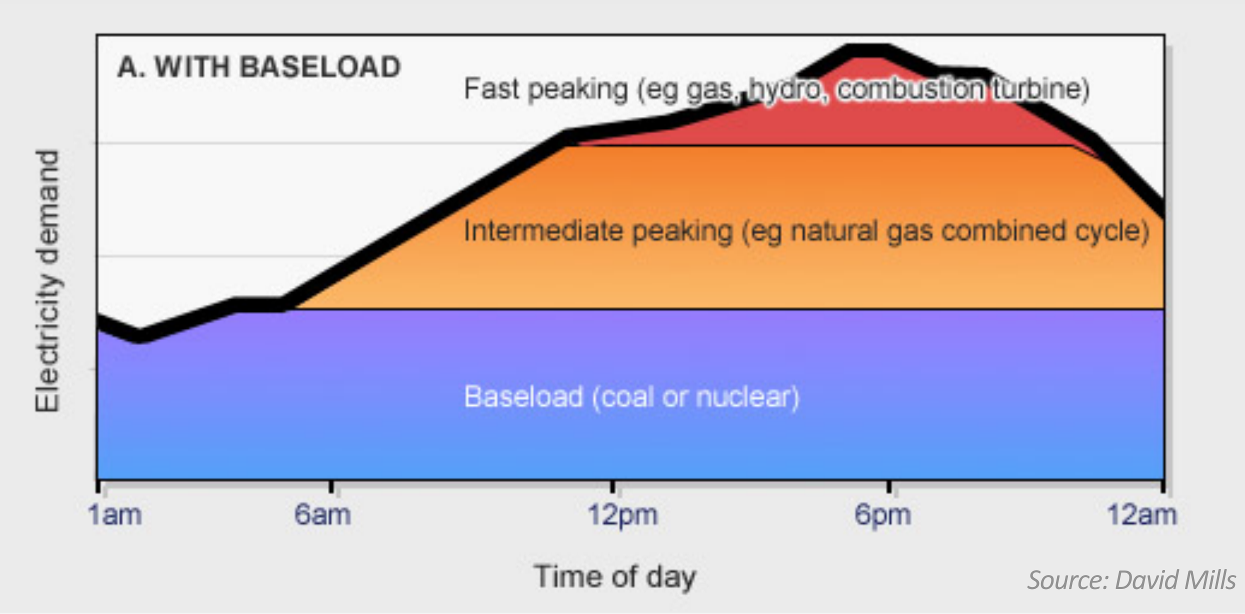
The first decade of the twenty-first century saw a remarkable rise of renewable energy on the U.S. electric grid. The second decade will see an equally impressive rise of energy storage.

For 100 years, the electric grid remained relatively the same. Electric utilities ran large, fossil-fuel and nuclear power plants around the clock and have met fluctuations in power demand with fast-response gas, diesel and other (often inefficient and dirty) power plants.

When the grid was designed, engineers anticipated periods of peak energy use, typically the late afternoon on a summer's day.

Meeting demand meant layering power generation. The lowest level was big, inflexible, expensive-to-build but cheap-to-run, always-on "baseload" coal and nuclear power plants. The highest level was flexible, smaller, cheap-to-build but relatively expensive-to-run, "peaking" generators, until the energy supply was sufficient. Figure 1 illustrates.

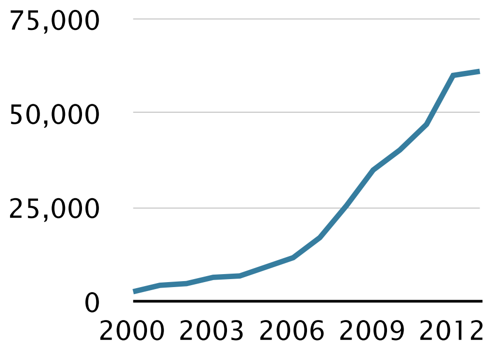
Figure 1. 20th Century Grid Design



Source: David Mills

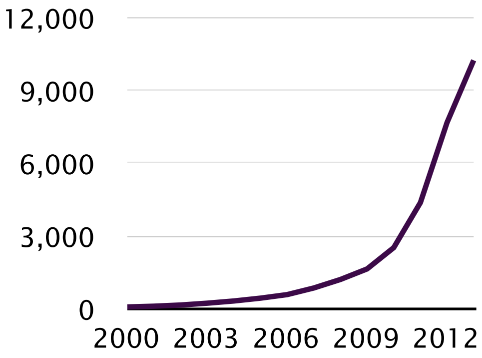
Today, 30 state renewable energy standards, combined with the rapidly falling cost of wind and solar power have changed everything, including the basic operation of the power grid. In the near term, renewable energy – especially solar – is rapidly reducing demand for all traditional fossil and nuclear power generation.

Figure 2. U.S. Installed Solar Electric Capacity (Megawatts)



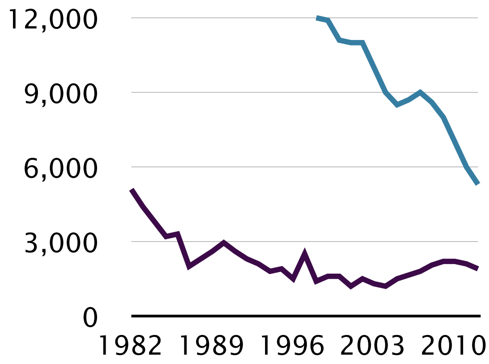
Source: Source: Solar Energy Industries Association

Figure 3. U.S. Installed Wind Power Capacity (Megawatts)



Source: Lawrence Berkeley Labs

Figure 4. U.S. Installed Cost of Wind and Solar Power ($/kilowatt)



Source: Lawrence Berkeley Labs

Instead of layering additional power plant capacity to meet a period of peak demand, future-forward utilities will focus on flexibility. In the long run, renewable energy will completely transform the grid's design.

Utilities will start leveraging smart grid technology to adjust the top of the electricity demand curve, as illustrated in Figure 5. They will do this by helping customers shrink their usage and shift their electric demand. Overall, this will reduce the size and duration of peak energy demand.

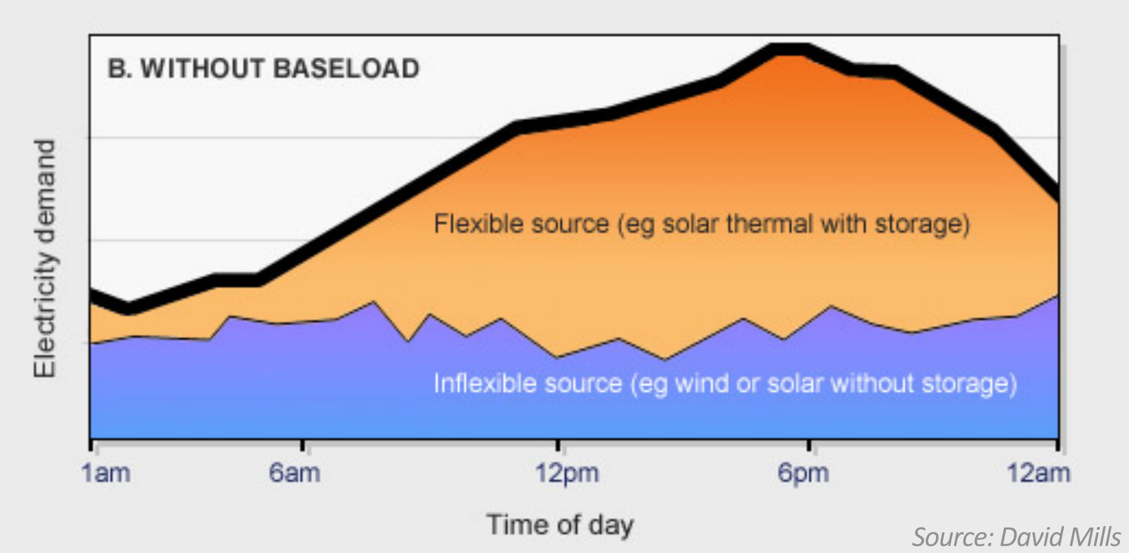
In addition, utilities will seek flexible sources of power to fill the shrinking gap between renewable energy supply and more flexible demand. Energy storage will be particularly effective at managing very short periods of variability in energy use or production.

The ability of many energy storage technologies to respond quickly to demand will help maintain the quality and reliability of grid electricity. The electricity system requires several basic elements to remain in balance at all times:

- Quantity - the amount of energy being consumed must match energy being produced.
- Quality - the voltage of electricity (e.g. 110 volts for household use) and the frequency (60 cycles per second, or 60 Hertz) must remain within narrow tolerances.

Thus, quick and accurate response is the key characteristic of power sources providing "ancillary services" to balance quantity and quality of electricity. Battery storage is the fastest and most flexible electricity source.

Figure 5. 21st Century Grid Design

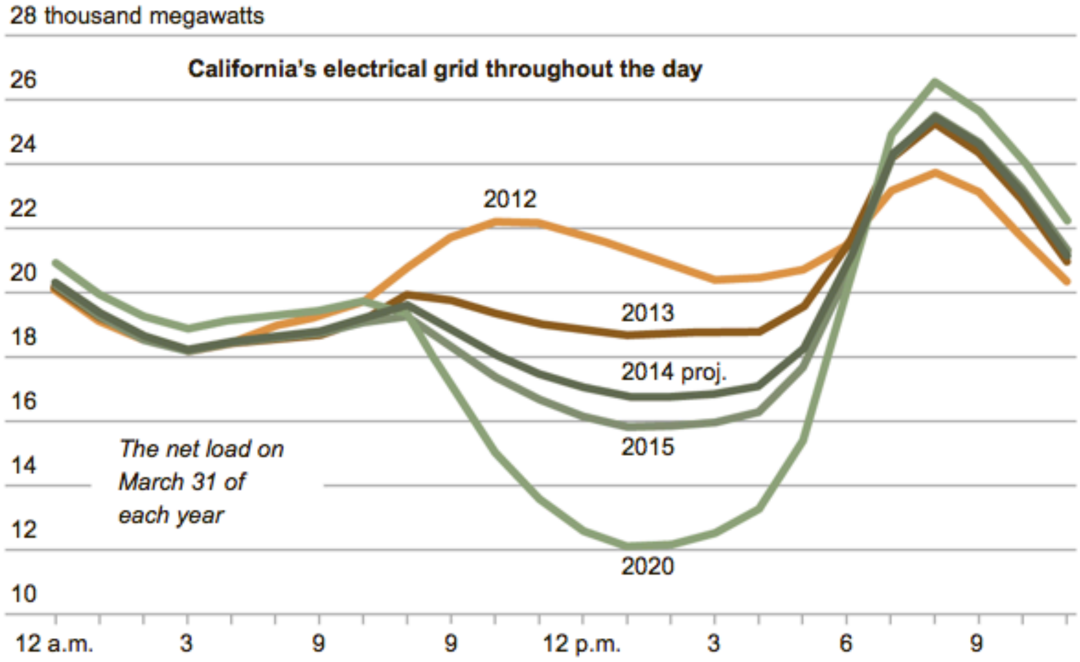


Source: David Mills

The Coming of the Duck

The changes to the U.S. electricity system have been negligible until now, but the particularly fast rise of solar power in California illustrates how renewable energy is changing the grid.

Figure 6. "The Duck"



Source: CallSO

Figure 6 shows the net supply/demand on the California grid (courtesy of the California Independent System Operator) for 2012-13 and forecast through 2020. Until 2012, daily energy demand looked like a two-humped "camel," with peaks mid-morning and early evening. Utility operated power plants supplied most of the needed energy. But the substitution of local solar power to meet local energy needs affects the demand for mid-day energy from the grid. The daily demand curve transforms, from a camel (orange line) to a (forecast) "duck" (bottom green line.

The duck has utility companies calling "fowl." In particular, the trough created by mid-day renewable energy production may cut into baseload power generation, as well as potentially requiring a dramatic ramp up in power generation in the late afternoon, as solar wanes. This alarms utilities, because they stand to lose revenue from their baseload power plants as well as from their peaking power plants that will run less frequently. Due to the bottom line threat, utilities point to the duck chart as evidence that renewable energy development should be stopped.

Ultimately, the duck highlights the limitations of using a twentieth century grid model (Figure 1) for a twenty-first century electricity system (Figure 2). Organizations like the Clean Coalition and Regulatory Assistance Project have "decoded the duck." Their work has shown how a smarter grid and energy storage can easily solve the purported problems.[2]

Flipping the Grid

The transition to a twenty-first century grid is largely about changing two factors: economics and grid operations.

Economically, an abundance of low-cost renewable energy will change the profitability of baseload and peaking power plants. Baseload power plants will suffer from a drop in wholesale electricity prices, as has happened in Germany.[3] Fast-response power plant operators will also struggle, because while peak energy prices may remain high, more solar energy on the grid will shorten periods of peak energy demand for these power plants.

Operationally, it means the grid layering process (Figure 1) gets flipped on its head. Although renewable energy generation still has some inflexibility, like old baseload coal and nuclear power plants, it has no fuel costs and near-zero operating costs. Thus, it's the first power a utility should want to use on the grid.

Fluctuations in wind and solar power production, however, mean grid operators want remaining power generation to be flexible and at a low capital cost. This conundrum leads some researchers to suggest that "baseload is not compatible with a renewable energy future."[4]

With quick, flexible response to electricity supply becoming more important in a renewable energy future, energy storage technologies may provide a crucial solution.

The Rise of Distributed Energy Storage

Options for cost-effective bulk energy storage – using large water reservoirs, underground salt caverns, or even railroad cars – do exist. In fact, over 95% of the 25,000 megawatts of deployed energy storage in the U.S. is pumped hydro reservoir storage (described more in the next section).

But the notion of large-scale energy storage doesn't necessarily reflect another ideal, the democratizing effect of renewable energy on the grid system.

Solar power in particular is allowing large power users, small businesses, and even individuals to reduce or eliminate their reliance on utility-delivered electricity. Their on-site energy production is meeting on-site needs, and in some cases, delivering excess power to the grid, thereby localizing the supply-demand balancing act of utilities.

The cost-effectiveness of on-site energy production demands immediate changes to the utility planning process. In fact, it should have changed 10 or even 20 years ago, long before the rise of distributed renewable energy made clear that large-scale, centralized power plants may become un-economical before they would reach the end of their useful 40- to 50-year useful life.

The changes to the grid aren't happening at the same pace everywhere. Some parts of the power grid (southern California, for example) have much more local renewable energy generation than others (e.g. Utah). Thus, the shift to a twenty-first century grid isn't a pressing, nationwide phenomenon (yet), but will soon become an urgent issue in some regions of the country.

Federal and state policies have begun to anticipate the need for energy storage. The Federal Energy Regulatory Commission issued two orders in July 2013 requiring transmission markets to pay more and more accurately for services provided by energy storage. Also in 2013, California passed a first-in-the-nation energy storage mandate that divides the 1.3 gigawatt (GW) target into transmission, distribution, and customer-sited storage.[5]

These timely policies will support innovative ways that that energy storage is already being introduced to the local energy grid, supporting local power production and the democratization of the energy system. This includes electric vehicles, community solar, island power grids, and microgrids.

What is Energy Storage?

Storing energy is a simple concept that encompasses a number of technologies. A simple Thermos® for example, uses insulation to store thermal energy by keeping "hot things hot and cold things cold."™

In the electricity system, energy storage means electricity storage. The difference between *types* of storage is the *medium* of storage. Figure 7 provides a few examples of energy storage based on the storage medium.

Types of Storage

Chemical storage includes batteries and fuel cells, which store electricity by reversing the chemical reaction that produces energy.

Thermal storage includes options like making ice or chilling water with electricity to be used to avoid electricity use at a later time for cooling or air conditioning. For example, the U.S. FDA microgrid (mentioned later) has cold water storage to operate chillers for air conditioning when grid power is lost. Some solar power plants also store heat in the form of molten salts, heat that can be used to make electricity when the sun doesn't shine.

One way to envision **potential energy** storage is moving something uphill with electricity and then generating energy when the thing moves downhill. A widely used technology involves pumping water up to reservoirs and then running it through turbines downhill at a later time.

An emerging concept (the first project is under construction in Nevada) is to use electricity to move gravel-loaded rail cars up a steep grade, generating electricity with regenerative braking on the way down.[6]

Kinetic energy storage involves storing energy in motion. A simple example is an electric vehicle like the Tesla Model S, which recaptures vehicle motion to charge the battery as the car slows. Pure grid storage models use flywheels, specially designed wheels that spin thousands of times per minute at low resistance.

Figure 7. Energy Storage Technologies

Medium	Technology
Chemical	Battery
	Fuel Cell
Thermal	Ice
	Water
	Molten salt
Potential	Hydro
	Rail car
	Compressed air
Kinetic	Flywheel
	Regenerative braking

Source: Institute for Local Self-Reliance

The different storage media have varying strengths and weaknesses for meeting grid needs. Some are quick to respond, but slow to re-charge. Others are slow to respond, but very cost-effective. Even within particular technologies there are differences.

Differences in Batteries

Traditional dry-cell batteries (e.g. AA, lithium ion laptop batteries, or lead acid car batteries) have internal cells with an electrolyte solution that generates energy. Because the components are integrated and self-contained – the "juice" is on the inside – maximum instantaneous output of a dry cell battery and the maximum total energy capacity are fixed.

Alternatively, flow batteries literally keep the juice on the outside, in separate storage tanks. The levels of fluid in the tanks represent the storage capacity of the battery, and they supply electrolytes to a fuel cell. The size of the fuel cell limits the instantaneous output of the battery, but because the electrolyte tanks can vary in size, a flow battery can provide much longer periods of energy storage at the same capacity as a dry cell battery.

Based on design and materials, batteries also have different charging speeds, charging cycles (number of times battery can be fully charged), and cost.

Empowering Local Energy

The electricity system has several energy storage applications, including enabling individuals and communities to maximize their use of local renewable energy resources. With storage, more locally produced renewable energy can be used on-site and more can be successfully integrated into a local grid system.

Already this is happening. Electric vehicle owners have installed solar panels, using clean energy from their rooftop to supplant fossil fuels in their cars. Community solar projects have added batteries to help solar serve early evening demand and smooth solar output. Utilities are using storage to increase the use of distributed renewable energy. Corporate and college campuses have created microgrids, using storage with renewable energy to create a mini electric grid that can remain powered even when the larger utility grid goes down.

The following examples illustrate how energy storage is helping increase distributed renewable energy development, and/or supporting individuals and communities in their effort to take control of their energy future.

Electric Vehicles

An electric vehicle (EV) may be the ultimate in democratic energy storage, and for good reason. It can store on-site energy production from clean solar energy and offset expensive and dirty petroleum fuels. EVs enable the expansion of both energy storage (the vehicle's energy source) and renewable energy (through its ability to utilize variable solar and wind resources).

With grid electricity, electric vehicles can significantly reduce greenhouse gas emissions from driving compared to typical gasoline power vehicles.[7] Combined with on-site solar power production, electric vehicles can use clean solar power for emission-free driving. With implementation of existing technologies, the car battery can also serve as a crucial backup when grid power fails.

Owners of electric vehicles recognize the opportunity, with 39% of surveyed electric vehicle owners in California already owning a solar array, and a further 17% planning to invest in one (Figure 7).[8]

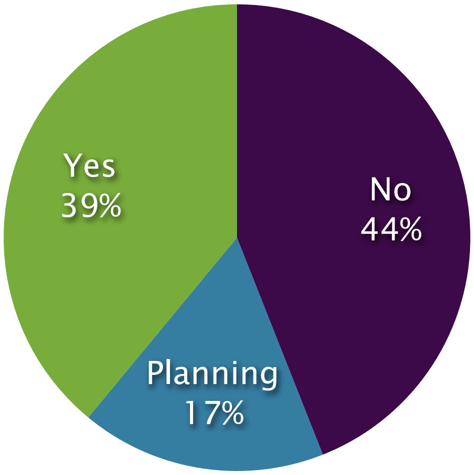
On-site solar has benefits regardless of storage, reducing energy bills and retaining more of an individual's energy dollar within their community.

Likewise electric vehicles possess inherent benefits. At typical grid electricity prices (about 12¢ per kilowatt-hour), the cost of driving an electric vehicle is equivalent to driving a gas vehicle for $1.20 per gallon of gas.[9] More efficient and simple electric motors also mean one-third lower maintenance costs over the life of the vehicle than gasoline combustion engines.[10]

Although rooftop solar electricity is typically more costly than grid electricity for most homeowners (for now[11]), it's still a cheaper fuel than petroleum, as the following table (Figure 9) illustrates for drivers in 9 large metropolitan areas (see endnote for cost assumptions).[12]

The cost of driving an electric vehicle can be reduced further with tailored utility billing plans, such as ones offered by Southern California Edison. Their EV plans offer discounted prices for vehicle charging in late evening or overnight hours. For moderate energy users, charging their vehicle after 10pm could cut the annual cost of their vehicle fuel by 33%. For higher energy users (using more electricity overall per month), the cost savings rises to 60% (Figure 10).[13]

Figure 7. Percent of EV Owners with a PV System



Source: Center for Sustainable Energy California u- Vehicle Survey Results May 2

Some utilities have an even better deal. Texas utility TXU is offering "free charging nights" to EV owners, from 10pm to 6am because of an abundance of overnight wind energy production.[14]

Figure 8. Popular Electric Vehicles

Name	Battery Capacity (kWh)	Advertised Range
Ford Focus	23 kWh	76 mi.
Nissan Leaf	24 kWh	73 mi.
Chevy Spark	21 kWh	82 mi.
Honda Fit	20 kWh	82 mi.
Tesla Model S	60 kWh	194 mi.

Sources: Ford, Nissan, Chevy, Honda, and Tesla Motors

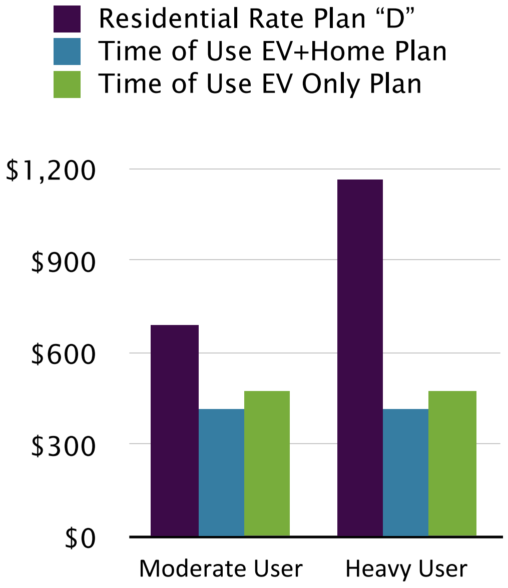
Figure 9. Cost to Drive an Electric Vehicle

	Cost per "Gallon"	
Location	**Grid power**	**Solar power**
Gasoline engine – $3.15 per gallon		
Dallas	$1.18	$1.42
Philadelphia	$1.44	$1.63
San Francisco	$1.46	$1.42
New York	$2.41	$1.68
Washington, DC	$1.16	$1.68
Miami	$0.99	$1.46
Los Angeles	$1.23	$1.35
Chicago	$1.18	$1.75
Minneapolis	$1.09	$1.63

Source: Institute for Local Self-Reliance

Combining solar and electric vehicles can accelerate the clean energy benefits and help Americans keep more of their energy dollar local. Already, electric vehicle manufacturers like Ford are offering low price solar arrays to electric vehicle buyers.[15]

Figure 10. Annual Cost of Electric Vehicle Charging



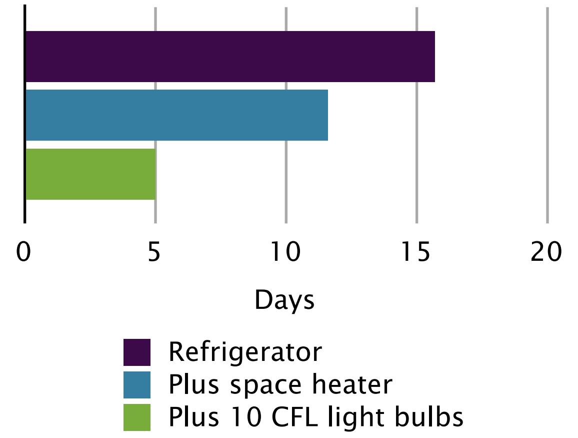
Source: Southern California Edison, Institute for Local Self-Reliance

An electric vehicle could also provide valuable energy backup when power from the grid fails. A typical electric vehicle battery (22 kWh) could power a refrigerator for nearly two weeks (at 1.4 kWh per day). With a rooftop solar array, an individual with an EV connected to their house could have backup power for a long period of time, if needed (Figure 11).

Using an EV battery for backup requires the spread of vehicle-to-home communication technology as well as potential policy changes to prevent battery power from flowing back to the grid.

Charging electric vehicle batteries with local solar could power most of the driving Americans currently do. The 2.5 kW solar array offered by Ford and Solarcity for buyers of the Focus Electric would produce enough energy on an average day (in an average city) to fill 40% of the battery. The resulting range of 30 miles is more than the daily distance driven for 60% of America's cars (Figure 12).[16] If 10% of those vehicle owners converted to electric drive and installed a solar array, it could cut annual U.S. carbon dioxide emissions by 31 million metric tons, the equivalent of removing 6 million vehicles from the road.[17] (Note: the vehicles would not always be home to charge off the solar array, so the greenhouse gas emissions is a net effect, not a direct one).

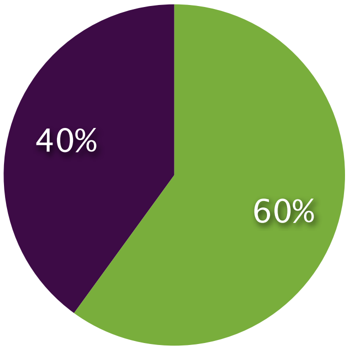
Figure 11. Days of Backup Power from EV Battery



Source: Institute for Local Self-Reliance

Electric vehicle storage can also be used in aggregate to increase penetration of renewable energy on the grid. A 2006 study conducted by Willett Kempton of the University of Delaware and Cliff Murley of the Sacramento Municipal Utility District suggested that EV batteries could provide ancillary services but also enable a "much larger penetration of intermittent renewables."[18] A 2011 study by the Pacific Northwest National Laboratories illustrated how large-scale deployment of electric vehicles in the seven-state Northwest Power Pool could double the wind power on the regional grid system by absorbing excess wind power production at times of low demand, adding 10 gigawatts.[19]

Figure 12. A 2.5 kW Solar Array Could Cover All Daily Miles Driven for 60% Percent of Cars



Source: Institute for Local Self-Reliance

Finally, when vehicle batteries no longer have the capacity to power vehicles, they may still have enough capacity to provide energy services to the electric grid.[20]

The bottom line:

1. Solar and electric vehicle batteries can combine to allow for carbon-free driving at a lower cost than using a gasoline car
2. An EV battery could provide a home with a useful battery backup in case of emergency, and
3. Many EV batteries together, during and after their use in vehicles, can help expand renewable energy on the grid.


Source: Argonne National Laboratory

*A 2011 study by the Pacific Northwest National Laboratories illustrated how **large-scale deployment of electric vehicles** in the seven-state Northwest Power Pool **could double the wind power on the regional grid system** by absorbing excess wind power production at times of low demand, adding 10 gigawatts.*

Community Solar and Storage

Energy storage may become a key feature of community solar projects, also called "solar gardens." Although ownership structures vary for community solar projects, a number are owned and operated by cooperative electric utilities on behalf of their members.

In one project recently completed in Minnesota, the Wright-Hennepin Electric Cooperative combined 40 kW of locally manufactured solar panels with 36 kW of locally manufactured battery storage.[21] The batteries provide the project with at least two key advantages, with more possible as the grid system changes upon the arrival of more renewable energy.

Wright-Hennepin Community Solar, MN
Source: Clean Energy Collective

The battery's primary value is solving the "duck" problem mentioned in the introduction – shifting the use of solar energy produced in the afternoon into the peak early evening period.[22] But the unique configuration of the batteries and solar panels is helping in several subtle ways. Steve Nisbet of the cooperative utility explains:

> "*We're using the same inverters [which convert direct current solar energy into grid-appropriate alternating current] for the batteries and the solar panels, [saving] the cost of having two sets of inverters.*"[23]

In addition to hardware savings, the utility is achieving higher efficiency. The solar panels can pump energy directly to the batteries (without the loss during conversion to alternating current) because the panel links directly into the batteries.

Also, the link through the batteries gives the utility fine-tuned control over the amount of electricity that goes to the grid. The utility can put exactly as much energy as it desires onto the local grid, any excess power continues to charge the batteries.

> "*One other oft-missed benefit is that I can use the batteries and inverters to maintain a stable output while I'm servicing parts of the system, which minimizes any lost energy production from the solar panels during maintenance windows.*"[24]

The batteries may offer other (monetary) benefits in the future. Nisbet explains:

> "*We're not using them for anything but demand reduction…right now. In the future we may use the batteries for [frequency regulation, voltage support, or capacity*

> *firming]. Frequency regulation is done in other [independent system operator or ISO] markets around the country (California for example), but right now, the [Midwest] market hasn't needed it (at least on the scale we're talking about).*
>
> *"At some point in the future that will change. The same goes for firming and voltage support. The solar penetration in our area is so small right now that the existing grid equipment can follow the voltages just fine.*
>
> *As we've seen in Hawaii, Arizona, and California, as the penetration goes up,…energy storage at the local, or distribution, level becomes an imperative."*

Maximizing Local Storage and Kaua'i

When talking of balancing local supply and demand on the grid, there's no better example than an isolated, island power grid. On the Hawaiian island of Kaua'i, the cooperative electric utility is rapidly increasing the amount of solar energy on its 65 megawatt (MW) grid, supported by energy storage.

Kaua'i Island Utility Cooperative was formed in 2002, when a group of the island's business leaders helped finance a purchase of the existing electric company. Over the ensuing decade, the island's utility has started a massive transformation to renewable energy, all while giving its 30,000 members a growing ownership share in their utility.

The KIUC transformation to renewable energy was catalyzed by the 2008 spike in oil prices that struck all Hawaiian utilities and dramatically increased the cost of electricity. The cost of energy to consumers has risen by 10-15¢ per kilowatt-hour, 33% or more. Prices in Hawai'i are now 3-4 times higher than for average electricity customers in the rest of the United States.

By 2015, KIUC will likely quintuple its renewable energy from a decade earlier. In 2006, 8% of their electricity sales derived from renewable resources, rising to 15% of sales in August 2013. The utility projects a near-tripling to 42% renewable in two years, (by the end of 2015), split between biomass, hydro, and solar power.[25] More than a third of this, or 15%, will come from customer-owned solar arrays.[26]

The utility's strategic plan illustrates the remarkable level of customer-owned solar:

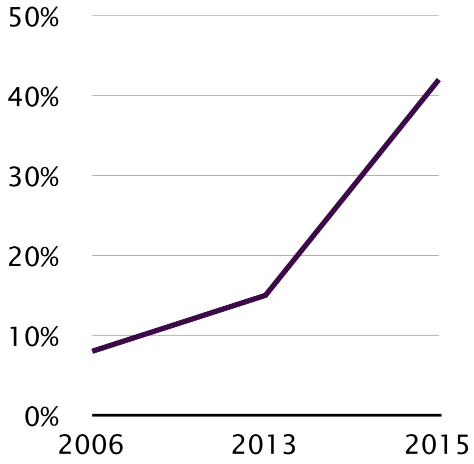
> *"By the end of 2012, more than 1,200 PV systems had been installed on Kaua'i, generating nearly 7 megawatts. In 2013, 1,500 more systems representing an additional 9 megawatts are scheduled to come on line."*[27]

Already, KIUC is ranked #2 among U.S. utilities in solar, with 282 solar Watts per customer installed in 2012.[28]

Solar is a good resource for Kaua'i, but not extraordinary. The National Renewable Energy Laboratory estimates electricity output of 1343 kWh for every installed kW DC of capacity per year, just 4.5% better than for Minneapolis, MN.[29]

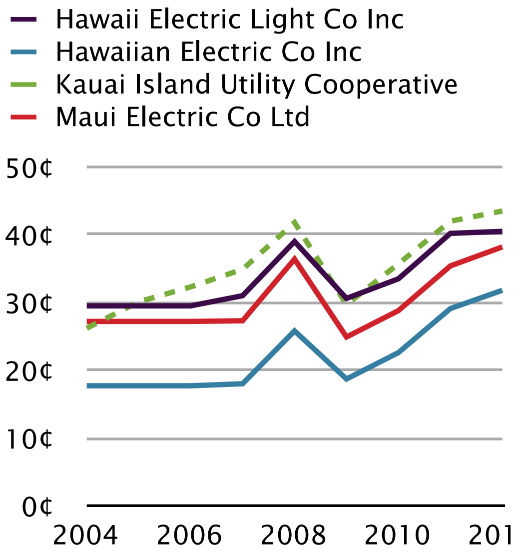
Energy storage has played a key role in the expansion of solar energy. The utility has deployed distributed battery storage (of up to 3 MW capacity) at two of its major substations, Koloa and Port Allen, to support utility-owned solar arrays ranging from 1.5 MW to 12 MW (under construction). In particular, "KIUC uses battery energy storage systems at the Koloa substation and at Port Allen to help stabilize the intermittent energy generated by solar projects."[30]

Figure 14. Kaua'i Cooperative Electricity, Percent Renewable



Source: KIUC

Figure 13. Retail Electricity Prices for Hawaiian Utilities



Source: KIUC

On the Hawaiian island of Lanai, utility managers have explicitly mentioned three ways energy storage helps accommodate solar power. First, it overcomes limitations of existing fossil fuel generation to handle "ramp rates," or the speed with which intermittent cloud cover can cause solar arrays to go from low to maximum production in a matter of seconds. It also backs up the solar capacity for cloudy days (called "firming"). Finally, the batteries help maintain a constant frequency for the grid's alternating current.[31]

The presence of storage has helped the Kaua'i utility push solar energy generation to unprecedented levels. The forthcoming 12 MW solar project being constructed at its Koloa substation will provide 30% of the island's daytime electricity demand, supported by an additional 2 MW of battery storage.[32] [33] This will join an existing 6 MW solar PV project completed in 2012.

Beyond Net Metering

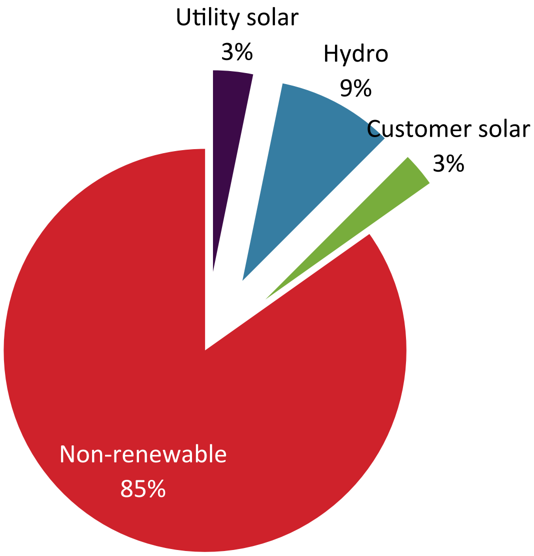
Kaua'i's electric utility was one of the first to hit its aggregate limit on net metering (1% of energy sales) in 2008. The utility discontinued net metering and replaced it with a (lower cost) feed-in tariff program: paying 20¢ per kilowatt-hour from small-scale solar arrays over 20 years.

The 3 MW program supports projects up to 200 kW in size and, when fully subscribed, will provide close to 4% of the island's peak energy use.

Combined with other programs, KIUC expects to get approximately 6% of its energy from customer-owned solar by 2015.

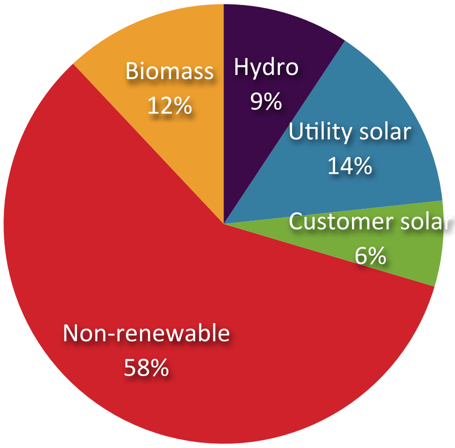
Citations.[31]

Figure 15. KIUC Energy Mix 2013



Source: KIUC

Figure 16. KIUC Energy Mix 2013 + Under Development



Source: KIUC

Combined with other projects in the pipeline, the utility plans to meet half of the daytime energy use on Kaua'i with solar by the end of 2015.[34]

Energy storage has other benefits, as well. It can reduce operations and maintenance costs for the island's fossil fuel power plants. An energy storage study conducted by the utility and Sandia National Labs showed an annual net savings of $135,000 (about 1% of the utility's operations budget) in operations and fuel costs for the utility using energy storage with existing diesel and gas power plants.[35] Some have called this the "Prius effect," referencing how the car's battery helps the internal combustion engine run at its most efficient.

As solar and wind prices continue to fall, and fossil and nuclear prices continue to rise, other utilities must learn from KUIC's use of energy storage to provide balancing on the grid, and to maximize the deployment of renewable energy.

Microgrids

A microgrid is an area of the electricity system that – at the flip of an automated switch – can operate on its own (managing supply and demand) independent from the larger electric grid.

Microgrids are rising in popularity as affordable distributed renewable energy generation and energy storage make it possible to operate a small scale version of the electric grid with local control, to dramatically increase renewable energy, to maintain a reliable power supply, or all of the above.

According to microgrid developer Green Energy Corp., in late 2013, there were only 30 "commercial-scale" microgrids in operation, but no description of the 30 or their size.[36] Navigant Research predicts exponential growth in microgrids – to as much as 6 gigawatts by 2020 – as the costs of locally generated and controlled power fall relative to grid electricity prices.[37]

A Key Role for Storage

Energy storage enables two key features of microgrids: islanding and local grid management.

Independent operation – "islanding" – is an essential characteristic of a microgrid, but it's not the only one. There are many other useful features that have motivated businesses, government agencies, and college campuses to develop microgrids.

As mentioned in the UC San Diego case study, reliable power supply was essential for sensitive electronic equipment. On-site power generation and energy storage allow it to avoid costly down-time and re-calibration of such equipment when the grid goes down.

Energy storage plays a particularly important role in managing ancillary services for a microgrid. Storage, like a battery, can not only supply real power when other generators aren't functioning, but can also provide ancillary services ordinarily found on the larger electric grid's distribution network, including frequency regulation, load following, and voltage management.

The following microgrids feature energy storage for their islanding/backup capability.

Laurel, Maryland

One microgrid model was christened by the Maryland governor and the chairman of the Federal Energy Regulatory Commission in October 2013. It includes 402 kW of solar PV over carports along with a shipping container stuffed with lithium ion batteries at a mixed-use development in Laurel, MD. The solar energy provides 20 percent of the site's energy needs, and the batteries have enough capacity to provide 50 kW of power for 4 hours.[38]

The site has the two essential elements of a microgrid: on-site power generation (from solar) and backup (from batteries) that allow the site to operate for hours without grid power.

Interestingly, the system pays for itself with its grid connection rather than its ability to be disconnected.

*A **microgrid** is an area of the electricity system that – at the flip of an automatic switch – can operate on its own (managing supply and demand) **independent** from the larger electric grid.*

The battery system provides value to the grid in the form of [frequency regulation](). In short, the microgrid operator signs up as a regulator with a stated capacity in the regional market. When sent a signal that regulation is needed, they must respond or pay penalties for being unavailable. Batteries are particularly effective for this task, because they can respond almost instantly to the needs of grid operators. Quick bursts of power from the site's batteries replace expensive and polluting power from natural gas power plants that normally previously helped the utility regulate grid frequency, and pay for the cost of energy storage.

However, this commercial opportunity is limited to a few grid regions, like PJM Interconnection in the northeast, that have active markets for frequency regulation and reasonable prices.

Between 20% on-site renewable energy and the cost-effective use of batteries, the Laurel microgrid holds much promise for replication in areas where grid operators pay for frequency regulation on [ancillary services markets]().

San Diego, California

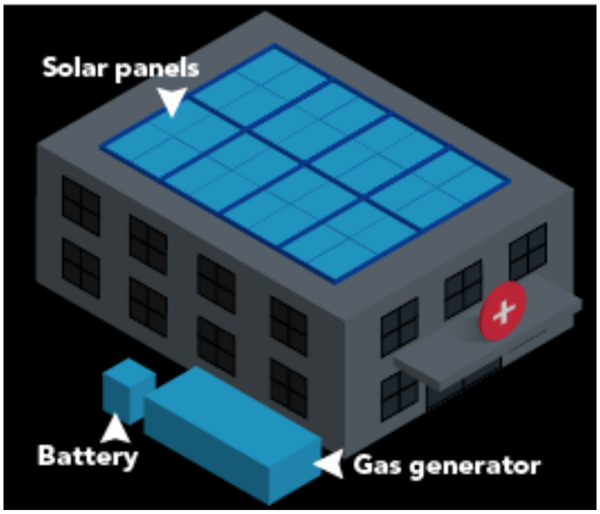
The University of California at San Diego illustrates how microgrids work well for corporate or college campuses. Originally, the school had backup power installed to protect fragile research equipment.

> *"We have an electron microscope that every time we have a supply disruption, it takes six weeks to recalibrate. We can't let that happen," says the University's research director.*[39]

By 2013, the campus had evolved its basic backup systems into a sophisticated microgrid, including renewable and conventional power sources such as:

- 2.2 MW of solar
- 2.8 MW from a methane-powered fuel-cell (methane from landfill gas)
- Two 13.5 MW combined-heat-and-power gas turbines
- A 3 MW steam turbine
- Several hundred kW of battery storage

Figure 17. Illustration of microgrid



Source: Bloomberg

- Steam and electric chillers to store cool water at night for building cooling during daytime

The microgrid supplies over 92% of campus electricity needs and 95% of heating and cooling, with both thermal and battery energy storage.[40]

The next phase of the microgrid will saturate campus rooftops with solar power. Combined with new research into solar energy forecasting, it will help the campus significantly increase the portion of its energy that comes from renewable energy, currently less than 15% (from solar and the fuel cell).[41]

The 42 MW of power generation capacity (enough to power over 8,000 homes) and ability to isolate from the larger electric grid provides "low-cost, high[ly] reliable electric service to the buildings" on campus, says John Dilliot, Energy Utilities Manager.[42] During a 2011 blackout, for example, the campus was able to reduce power consumption in buildings, tap into thermal energy storage (cold water tanks), and cycle off building cooling to maintain power for essential services.[43]

The campus is also being redesigned to support charging of electric vehicles from renewable resources (solar and methane fuel cells) during peak periods. Several dozen fast charging stations will be set up, and on-site solar panels will allow for direct charging of vehicles, preventing power losses associated with transforming the power from direct current to alternating current (and back again).[44]

UC San Diego will continue to be a model for microgrid design, especially cost-effectiveness; the microgrid "saves [UC San Diego] an estimated $850,000 a month on its electricity bill,"[45] largely due to the economics of generating their own power at high efficiencies with combined-heat-and-power.

U.S. FDA – White Oak, MD

The White Oak Federal Research Center has sufficient on-site generation from gas turbines and diesel generators to power the entire campus, with chiller backup for air conditioning, based in large cold water thermal energy storage tanks.

Borrego Springs, CA

This jointly-funded pilot project of SDG&E and the U.S. Department of Energy was designed to test out advanced energy storage, reduction in local peak loads, and local resilience. The microgrid (including customer-sited solar, battery storage, and diesel generators) automatically restored power to 1/3 of local customers after storm outage knocked out all power in Sept. 2013.[46]

Removing Barriers to Storage

Several policy barriers have limited opportunities for energy storage to participate in the electricity marketplace, but that may be changing. Two recent orders (July 2013) by the Federal Energy Regulatory Commission (FERC), numbers 755 and 784, require grid operators – often called Independent System Operators – to factor in speed and accuracy of ancillary services into their market prices.[47] Because energy storage, like batteries and flywheels, is more responsive and accurate than traditional services (like natural gas power plants), this should result in more economic opportunity for energy storage (and higher quality grid power).

Markets for Ancillary Services

The FERC orders will help remedy a lack of consistent markets to sell energy storage services. Ancillary services like voltage support and frequency regulation are handled exclusively by monopoly utilities in many regions of the country, and regional grid operators have not necessarily established pricing and policies for including third parties. The FERC orders promise to change this in time, but it will likely be several years before they are fully implemented by regional grid authorities.

Net Metering

Net metering is a billing policy that simply compensates solar owners for their energy generation. It spins the meter backward during the day when there is excess solar generation, for example, and forward at night. It treats on-site renewable energy production like any other method for reducing energy consumption, by having customers pay for their "net" energy usage (total use less on-site production) on their electricity bill. The policy mixes interconnection rules (how to connect), a technical and administrative set of requirements, with economics of billing (net metering).

Such policies typically make it much easier to connect a solar array to the grid, for example, than without them.

California utilities have recently raised objections to allowing energy projects that combine solar and batteries to use net metering. Their problem is that it isn't generally possible with net metering customers to tell if the energy they send to the grid comes from their solar array or their battery storage system. Utilities insist they should not be paying for energy stored from the grid in addition to power produced from solar.[48]

But blocking batteries from net metering isn't just about what kind of energy is fed to the grid, but about the ease and cost of connecting to the grid. Projects connecting under net metering rules cannot be charged "standby" fees (ostensibly to cover the utility's cost for having backup power available 24/7) or hefty fees for interconnection to the electric grid. The additional meter for the battery system that utilities desire, for example, could increase project costs by more than $1,300.[49]

In other words, the economic and policy battle between utilities and distributed energy storage may just be getting started.

Figure 18. Potential Functions of Energy Storage

Storage Grid Domains (Grid Interconnection Point)	Regulatory Function	Use-Case Examples
Transmission-Connected	Generation/ Market	(Co-Located Energy Storage) Concentrated Solar Power, Wind+Solar Storage, Gas Fired Generation + Thermal Energy Storage
		Stand Alone Energy Storage, Ancillary Services, Peaker, Load Following
	Transmission Reliability (FERC)	Voltage Support
Distribution-Connected	Distribution Reliability	Substation Energy Storage (Deferral)
	Generation/ Market	Distributed Generation + Energy Storage
	Dual-Use (Reliability & Market)	Distribution Peaker
Behind-the-Meter	Dual-Use (Reliability & Market)	Distributed Peaker
	Customer-Sited Storage	Bill Mgmt/ Permanent Load Shifting, Electric Vehicle Charging

Source: California Public Utilities Commission

What Storage Does

The most common notion about energy storage – storing electricity for use at another time – explains just a small fraction of the technology's potential. In fact, other uses for energy storage like maintaining consistent voltage (and other "ancillary services") are often more useful and more lucrative.

Figure 18, from the California Public Utilities Commission (CPUC), shows the many potential functions for energy storage based on where it connects to the grid: on the transmission system, the lower-voltage distribution system, or behind the customer's electric meter.[50]

CPUC explains some of the enormous range of possible applications for energy storage. However, distributed energy storage may be the most economical and practical today. That's because grid-scale storage is better suited to large-scale services, but distributed storage can provide value at the local level. The following table, Figure 19, shared by Greentech Media smart grid analyst Zach Pollock, highlights how local storage provides access to more opportunities to earn a return with energy storage.[51] Peak shaving, especially for commercial customers, is particularly cost-effective.

Different energy storage technologies have different economic implications. For this report, we focus on energy storage in batteries because they are the most commonly deployed and versatile technology. Other storage technologies, such as pumped hydro, have little opportunity for expansion or limited applicability integrating with distributed energy projects.

Figure 19. Cost-Effective Applications for Energy Storage

	Trans-mission / ISO	Distribution	Customer-sited
T&D Deferral	x	x	x
Ancillary Services	x	x	x
Peak Shaving		x	x
Renewable Integration			x
Emergency Back-up			x
Demand Response			x

Source: Greentech Media

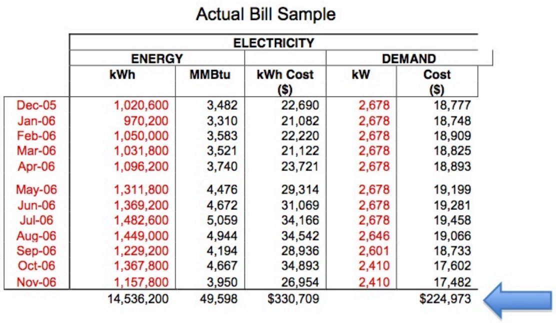
Balancing Energy Supply/Demand

Energy storage technologies (batteries in particular) allow customers to manage the time and amount of energy used from the power grid, and to insulate themselves from grid failures. These services fall into three broad categories.

Reducing Peak Demand

Many commercial electricity customers have a two-part electricity bill: one part for energy consumption and one for maximum demand. A hose metaphor helps explain: if these businesses were connected to the utility by a garden hose, they pay for all the water used (energy consumption) and for the hose to be large enough to meet their maximum need at any given time (maximum demand). This is in contrast to most residential customers that are charged only for the amount of water used, not for the size of the hose. Quite often, the demand charge is a large portion of the electric bill, sometimes as much or more than the charges for energy actually used.[52]

Figure 20. Sample Commercial Electric Bill



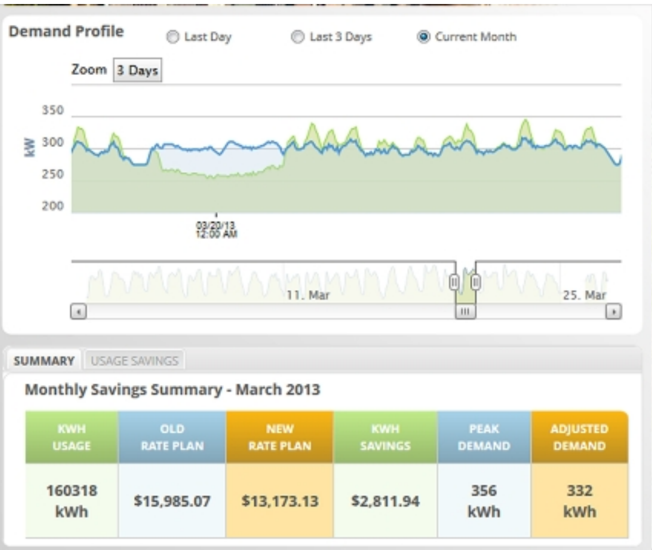
Actual Bill Sample

	ELECTRICITY				
	ENERGY			DEMAND	
	kWh	MMBtu	kWh Cost ($)	kW	Cost ($)
Dec-05	1,020,600	3,482	22,690	2,678	18,777
Jan-06	970,200	3,310	21,082	2,678	18,748
Feb-06	1,050,000	3,583	22,220	2,678	18,909
Mar-06	1,031,800	3,521	21,122	2,678	18,825
Apr-06	1,096,200	3,740	23,721	2,678	18,893
May-06	1,311,800	4,476	29,314	2,678	19,199
Jun-06	1,369,200	4,672	31,069	2,678	19,281
Jul-06	1,482,600	5,059	34,166	2,678	19,458
Aug-06	1,449,000	4,944	34,542	2,646	19,066
Sep-06	1,229,200	4,194	28,936	2,601	18,733
Oct-06	1,367,800	4,667	34,893	2,410	17,602
Nov-06	1,157,800	3,950	26,954	2,410	17,482
	14,536,200	49,598	$330,709		$224,973

Source: Eric Woodroof

Energy storage can allow customers that aren't often reaching their maximum consumption to shave their energy demand from the utility to reduce demand charges. Figure 21 shows how one business uses energy storage to reduce their peak energy demand, cutting their monthly energy bill by nearly 20%.[53]

Figure 21. Peak Shaving to Reduce Demand Charges



Monthly Savings Summary - March 2013

KWH USAGE	OLD RATE PLAN	NEW RATE PLAN	KWH SAVINGS	PEAK DEMAND	ADJUSTED DEMAND
160318 kWh	$15,985.07	$13,173.13	$2,811.94	356 kWh	332 kWh

Source: Doug Staker

Shifting Energy Use

Electric customers can also save money with energy storage if they are on a time-of-use billing plan, where electricity is more costly at certain times of day. The energy storage device allows them to buy power when it's cheap (at night or on weekends), store it, and tap that stored energy during the expensive periods (e.g. weekday afternoons).

Time-shifting using energy storage also benefits solar energy producers, who may find that they can get a better price from their utility when delivering energy later in the day while demand is high but there is less sun.

Finally, some utilities offer discounts to electric customers to provide controllable demand. For example, many utilities will provide a credit for customers that let the utility remotely cycle off their air conditioner for up to 15 minutes during periods of peak demand. Similar programs are available to commercial and industrial customers with large energy loads. Energy storage allows them to participate in demand response programs without having to turn off their air conditioners or electric motors.

Replacing "Spinning" Reserves

Since power demand can sometimes change unpredictably, electric utilities typically have one or more fossil fuel power plants operating as a "spinning reserve." In this instance, the power plant is primed to put more power onto the grid on very short notice. It does so by burning fuel, heating water, generating steam, and spinning its generators.[54] If unused, the utility dumps the energy produced into the ground rather than the grid.

Energy storage provides utilities with quick-response reserves, reducing the need for polluting and wasteful spinning reserves and allowing time for power plants that are off to spin up.

When not in use for other services, energy storage also represents excess capacity that utilities can tap into during periods of peak energy use. Energy storage is extra capacity utilities can use to meet unanticipated demand.

Providing Backup

Energy storage can also serve as a backup in the event of a grid power failure. The value of this varies based on the customer and their needs: from the cost of refrigerated goods to the cost of recalibrating electron microscopes (as at UC San Diego).

Delivering Ancillary Services

Everything designed to use electricity, from motors to iPad chargers, has certain expectations about the power it receives from the grid. In the U.S., most devices expect power delivered at approximately 120 volts. This is the akin to the water pressure in a pipe and it helps describe how fast the electrons are moving from the grid into our devices and motors. The reason for 120 volts is buried in the history of the electric grid.

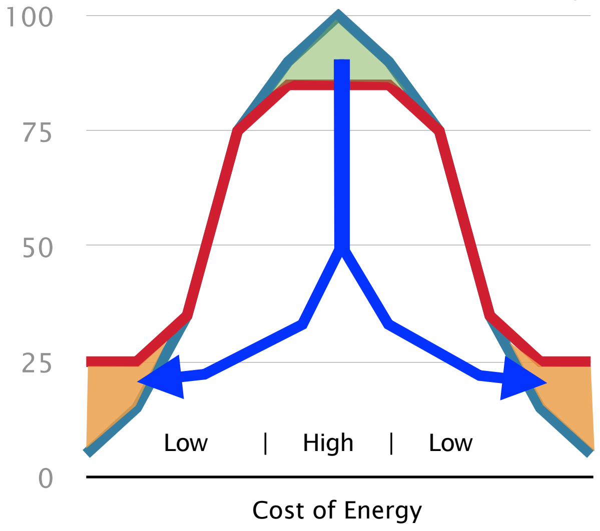
U.S. electricity is also delivered via alternating current with a frequency of 60 Hertz (meaning the voltage reverses 60 times per second). Most electricity in the U.S. is generated from the spinning motion of magnets within a coil of wire that creates a magnetic field. As the magnet spins, the magnetic field moves, causing alternating current. In a power plant, fossil fuels or nuclear reactions heat water to produce steam, which spins a turbine (with a magnet and coil inside).[55]

Small deviations in voltage and frequency are normal. But electrical equipment can malfunction and the local power grid itself can collapse if delivered voltage deviates significantly from 120 V or the frequency deviates significantly from 60 Hz.

Utilities can use energy storage to address variations in the voltage and frequency of grid energy. In fact, batteries are often more accurate and quicker to correct deviations in frequency and voltage than traditional power generation. Utilities can also network storage systems together (e.g. SMUD in Rancho Cordova, CA) to use distributed storage systems as though they were one large system.[56]

Figure 23, shows how energy storage has historically been rewarded in competitive electricity markets.[57]

Figure 22. Time-Shifting Energy Use with Storage



Source: Institute for Local Self-Reliance

Figure 23. Energy Storage Value in Competitive Electricity Markets

Market Type	Location	Years Evaluated	Annual Value ($/kW)
Time-shifting	PJM	2002-07	$60-115
	NYISO	2001-05	$87-240
	USA	1997-2001	$37-45
	CA	2003	$49
Regulation	NYISO	2001-05	$163-248
	USA	2003-06	$236-429
Contingency Reserves	USA	2004-05	$66-149

Source: National Renewable Energy Laboratory

Furthermore, supporting voltage is more efficient the closer a power plant is to demand. Traditional power plants are large, often dirty or noisy, and therefore frequently geographically distant from major population centers.

Energy storage, like electric vehicle batteries, can add power to the grid close to where energy is being used.

Maintaining a constant 60 Hz frequency is also essential for the power grid. Flywheels, along with fast battery technologies have the capability to follow variations quicker and more accurately than generators, leading to increased efficiency and less wear and tear on equipment.

Absorbing Excess Energy

Sometimes an imbalance in voltage or frequency is the result of too much power supply, rather than too little. Unlike traditional power plants, energy storage can help restore balance by absorbing excess power.

By being able to affect both sides of the supply-demand equation, energy storage can more efficiently help balance grid energy and support power quality.

Note: Under current market rules the operator of the system may have to pay for the energy absorbed off the grid, even if it was done for the sake of regulation.

Smoothing Ramp Rates

Improved forecast data is helping utilities plan for variable output from renewable energy power plants, but energy storage can help compensate for the sometimes rapid changes in energy output from renewable energy generators.

On the Hawai'ian island of Lanai, for example, battery storage is helping an isolated grid accommodate power fluctuations caused when intermittent cloud cover rapidly shades or uncovers a local solar PV system. While the PV array has a nominal output of 1500 kW, attached battery storage can absorb fluctuations of 360 kW every minute, giving grid operators time to deploy other resources to keep supply and demand in balance.

Figure 24 shows a very simplified model of how energy storage can smooth energy output from renewable energy systems.

Already, some areas of the electric grid, such as the Northeast, have markets where non-utility providers can bid to provide these

ancillary services. Orders from Federal Energy Regulatory Commission (FERC) in July 2013 will require markets to be established in all regions.

Reinforcing Infrastructure

Even if overall energy demand doesn't grow, demand in certain areas of the grid may grow faster than others. In the past, utilities have responded with more infrastructure – power plants and power lines – to make available more capacity to areas in need.

Strategically placed energy storage units (or distributed power generation, like solar) – near energy demand – can help utilities meet increasing peak load without new infrastructure.

"We can avoid that $100 million investment in transmission lines, distribution lines, in capital infrastructure," says Michael Deering, speaking of a recent solicitation by the Long Island Power Authority for 40 megawatts of new solar energy on the south fork of Long Island.[58] If successful, the Long Island program will help the utility avoid over $100 million in new power lines and power plants to meet rising local demand.[59]

Local power sources can also help reduce stress and extend the life of critical equipment (e.g. substations and transformers), by facilitating operation at less than full capacity.

Similarly, energy storage can help avoid capital expenses and extend the life of existing assets by shifting non-peak energy production to peak demand periods.

Supporting Renewable Energy

In combining a variety of useful features such as smoothing ramp rates and voltage/frequency management, energy storage allows the local electric grid (micro or otherwise) to accommodate more renewable energy. Hawai'ian utilities are the perfect example, as each island serves as a functional microgrid. Battery storage is paired with solar and wind energy to allow for much higher levels of renewable energy delivery (up to 40%) than are seen elsewhere.

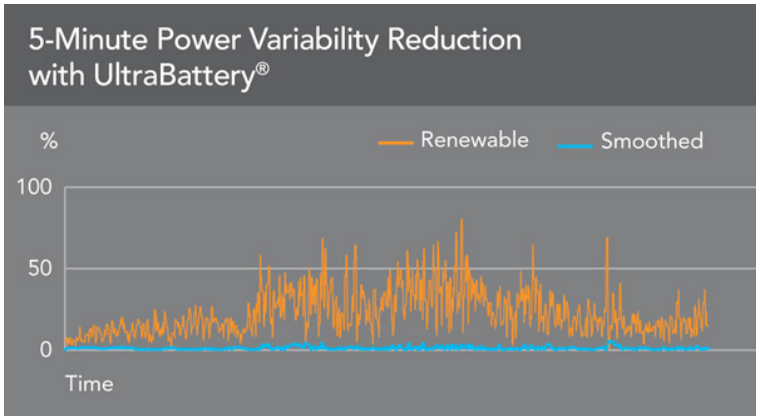
Energy storage can be especially important for distributed renewable energy, because the grid impact will be localized and relatively small, allowing distributed energy storage of modest size to work well in tandem with renewable energy.

The Future

Use of energy storage will continue to grow significantly, for three reasons:

1. Falling costs will permit utilities to more efficiently integrate high percentages of renewable energy;
2. Electric vehicles will continue to grow quickly as a cost-effective alternative to petroleum fueled vehicles; and
3. Businesses, individuals, and other entities will seek more control over their energy system, enabled by energy storage.

Figure 24. Energy Storage Value in Competitive Electricity Markets



Source: National Renewable Energy Laboratory

In all three cases, storage will aid the rapid deployment of renewable energy.

Batteries are likely to be the key storage technology. Already in wide commercial use in electronic devices from laptops to tablets to phones, millions of lithium-ion batteries are manufactured each year.

Mass production has driven the cost down. Figure 25 shows historical price decreases for lithium-ion batteries for consumer electronics.[60]

More recently, we can track decreases in battery costs from the consumer side. Price history of common laptop batteries on Amazon.com shows prices decreasing by two-thirds since mid-2010.[61]

Other reports suggest that prices (for bulk buyers) are down 75% in the past five years.[62] Tesla Motors' proposed "gigafactory" could, by itself, dramatically increase worldwide battery production capacity.

The potential for widespread use of batteries in distributed grid storage (as in Hawai'i), in electric vehicles, and as on-site energy storage for microgrids or individuals means that batteries are a potentially disruptive entrant into the electricity sector.

Large-format batteries suitable for use on the electric grid are already 60% cheaper than they were in 2009, according to Navigant

Research.[63] Navigant suggests they will decline in price by another 40% by the end of 2015, and a total of 60% from today's prices by 2020. Bloomberg Energy agrees, estimating a 57% drop in cost of energy per kWh from batteries by 2020.[64]

According to Sam Jaffe of Navigant Research, "At that point, EVs will carry only a small premium over their gasoline counterparts, and battery-based energy storage will be almost as inexpensive as natural gas generation in a peaker plant."[65]

Integrating Renewables

Batteries and other energy storage will help overcome the biggest drawbacks of grid connected renewable energy projects: variability.

In particular, utilities need to be able to accommodate a potentially rapid rise and fall of energy supply. Already, several reports illustrate strategies that utilities are implementing, with existing technology, to make renewable energy integration easier.[66]

If energy variability can't be handled with advanced forecasting and demand response, variability can be smoothed with batteries. In high-cost regimes like Hawai'i, batteries are cost-effectively enabling utilities to get as much as 40% of their energy from solar and wind by storing energy for cloudy or non-windy periods.

As the cost of energy storage falls, it will be increasingly cost effective for utilities of all types to use energy storage to blow past originally conceived limits on local and grid-wide renewable energy.

Powering Vehicles (and the Grid)

At the end of 2013, the U.S. had nearly 170,000 electric vehicles on the road, and the International Energy Agency predicts this will rise to 5.3 million by 2020.[67] The sticker cost premium for EVs will largely evaporate by then, and the cost of ownership will be lower, due to lower maintenance needs and the lower per mile costs of driving on electricity.

With vehicle-to-grid technology, EV batteries will also aid electric utilities by providing support for more renewable energy. A 2011 study by the Pacific Northwest National Laboratories showed that the seven-state Northwest Power Pool could add an additional 10 gigawatts of wind power – doubling the current installed capacity – if 1 in 8 vehicles in the region were battery operated.[68] This finding is supported by research from Denmark,[69] and could make an enormous difference in accommodating the variability of renewable energy generation.

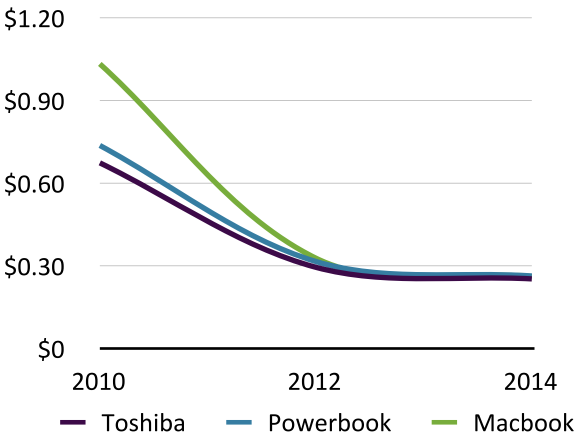
Enabling Local Control

Perhaps most importantly, energy storage is the catalyst allowing individuals and entities to separate from the electric grid entirely. Electric utilities have increasingly fought back against the threat of distributed renewable energy to their business model, and energy storage could allow electric customers to figuratively or literally cut the cord to the electric company a la cellphone users and the landline phone company.

With energy storage, microgrids will become increasingly prevalent and cost-effective alternatives to grid power, with the potential to operate increasingly on renewable energy alone.

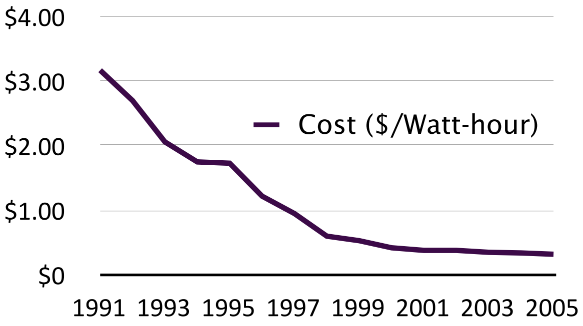
Sparked by poor grid resilience in the face of weather disasters like Hurricane Sandy, the public sector and regulators are pushing ahead. Connecticut created a statewide microgrid program that invested $18 million in 9 new projects in 2013. In New York, the governor has created a prize pool of $40 million to support the development of more disaster-resilient microgrids, each capable of serving 40,000 people.[70]

Figure 26. Price History for Selected Laptop Batteries ($/Watt-hour)



Source: camelcamelcamel.com, 2014

Figure 25. Lithium-Ion Battery Manufactured Price



Source: Duke University, 2009

Summary

The rise of energy storage is the second stage of a 3-stage booster rocket that's transforming the electricity system the way the Apollo mission did our view of outer space.

The first stage was the rise of renewable energy and the hint that the twentieth century fossil fuel electricity system was not immutable. It sparked the notion that electricity generation and ownership could be democratic rather than dictatorial. However, in places like Hawai'i or California, distributed renewable energy is ascendant and the fuel from that first booster stage is no longer sufficient to continue the journey to a twenty-first century electricity system.

Energy storage is the second booster stage. The examples in this report – community solar with storage, electric vehicles, and island grids – highlight the opportunity. Storage enables greater integration of renewable energy on the larger grid, high-renewable microgrids, and democratization of the electricity system, not just electricity generation. Already, new policies for energy storage in California, microgrids in New York, and energy services from FERC are enabling the continued growth of energy storage on the larger grid. Falling storage costs will make microgrids and electric vehicle ownership more effective, multiplying the capacity for local energy management and renewable energy production. Ultimately, as energy storage grows, the power in the energy system continues to trickle away from utilities and into the hands of their former customers.

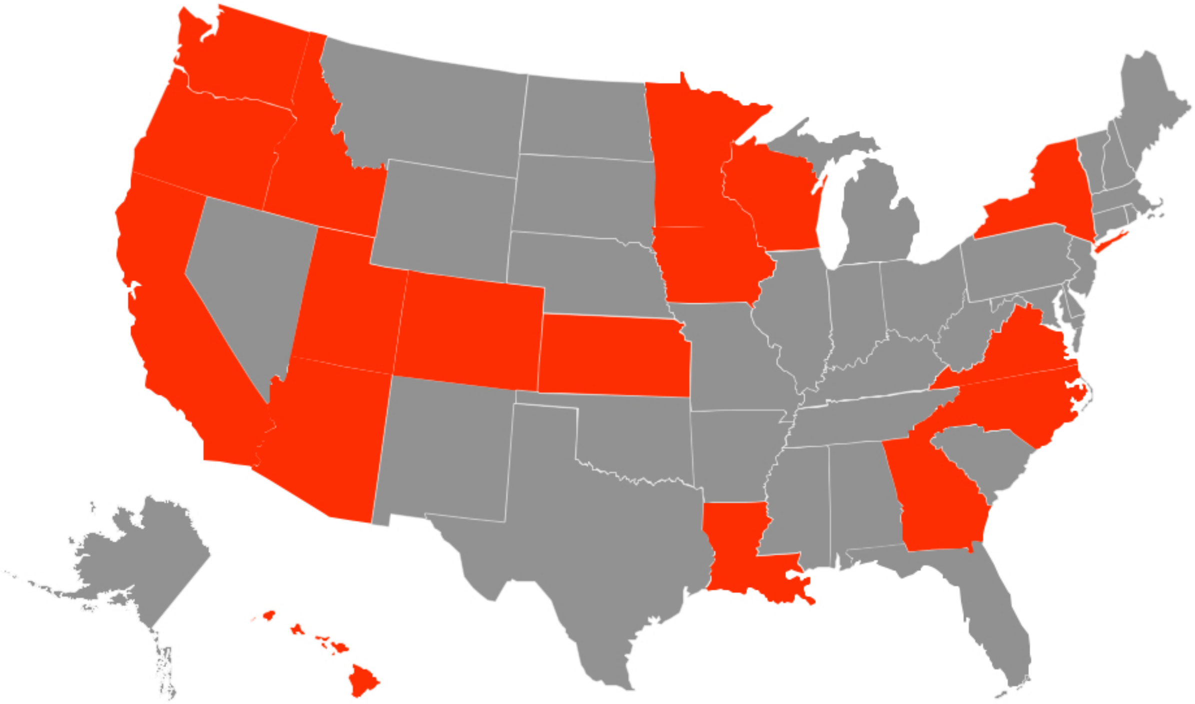
The third stage begins now, anticipating cost-effective longer-term storage and cheap short-term storage. These grid-flipping technologies will be cost-effective long before new utility power plants and power lines reach their 40- to 50-year lifespans. When they arrive, they not only make such investments obsolete, but inexpensive storage will aid in the retirement of legacy fossil fuel power plants. Inexpensive grid alternatives, enabled by cheap storage and local renewable energy, will be interconnected to create a more robust and resilient energy grid. In other words, the rules for today's electricity system must be changed to prepare for the third stage of the grid transformation.

Unfortunately, utilities haven't internalized what the combination of distributed renewable energy and energy storage mean for their monopoly energy model. Many still operate as though putting up defensive walls around their existing investments will secure their economic future, despite evidence that the coming decades will allow their customers to economically and completely cut the utility cord if it's no longer worthwhile to remain connected.

The completion of the 3-stage journey will dramatic. It will transform the electricity system into a 100% renewable, distributed network of intermingled energy producers and consumers, coordinated but no longer controlled by electric utilities.

The future of the electricity system is likely to reinforce the saying that "change is inevitable, growth is optional." The electricity system will transform, but we don't know yet if utilities will grow into their new role.

State Battlegrounds Over Distributed Generation



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- *$3.15 per gallon of gas*
- *23.6 miles per gallon average fuel economy for cars and trucks in 2012 (source below)*
- *2.5 miles per kilowatt-hour (kWh) for electric vehicles, 9.44 kWh per mile*

Assumptions for solar electricity cost:

- *Installed cost of $4/Watt*
- *Use of 30% federal tax credit*
- *80% of cost is financed at 5% interest*
- *Levelized cost over 25 years*

Source for fuel economy figure:
Plumer, Brad. Cars in the U.S. are more fuel-efficient than ever. Here's how it happened. (Washington Post Wonkblog, 12/13/13). Accessed 1/8/14 at http://tinyurl.com/mwux3wt.

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For the chart, customers were assumed to:

- *Plug in their car at midnight*
- *Charge the battery from half full to full*
- *Be in Tier 2 pricing for SCE for Moderate Users*
- *Be in Tier 3 pricing for SCE for Heavy Users*

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