EcoMotion – *Sustainability Solutions*

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A 2020 White Paper

Unpacking Energy Resilience

From Generators to Carbon-Free Microgrids

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Outline

Introduction

Energy Resilience is at the forefront of the electric power industry out of necessity, especially here in California where our utilities are shutting down customers through Public Safety Power Shutdowns (PSPS) that are crippling. Over New Year's I met a couple from Santa Rosa area. They'd been shut down six times this past fall by PSPS—once for an entire week. Everything in their fridge spoiled. This is tough stuff and indicative of a changing utility reality.

The classic utility obligation to serve is buckling under the heat of drought, high winds, aging electrical infrastructure, and arson. Without question, climate change is reaping havoc on communities across the country and around the world. We're experiencing extreme weather conditions with more frequent and more ferocious storms. The need for energy resilience is a direct result. "Climate Change" is now a "Climate Emergency." Energy Resilience is certainly a key element in preparedness.

Historical Perspective

In terms of electricity, energy resilience (then known as emergency back-up) is not a new concept. Most hospitals, police and fire stations, supermarkets, industries that rely on a steady source of power, and others have back-up in the form of generators on site. I know several homeowners that have installed generators, including most recently, my aunt. An aging senior, she wants to be able to use her stair climber. When the grid goes down, her generator will replace grid power in a matter of seconds. Generators are generally noisy, require considerable maintenance and testing, but are inexpensive and can back-up entire facility loads.

The Buzz Around Batteries

Much of today's excitement about energy resilience surrounds batteries. What EcoMotion calls "The Lithium-Ion Revolution" has ushered in a new era of resilience.[1] Tesla Powerwalls for homes are designed for resilience; Tesla Powerpacks are larger units for commercial buildings and industry. There are other leading battery energy storage manufacturers including Samsung and LG.

While the price of batteries is coming down, battery energy storage is still an expensive proposition, and thus usually relegated to judicial use. Most batteries are being used to offset peak power periods and to reduce spikes in peak demand that trigger elevated demand charges. By clipping these peaks, batteries create bill savings, offsetting their costs.

Batteries can be economically discharged to offset the highest price kWh and kW. They can be used for "energy arbitrage" whereby off-peak power is purchased, stored, and then discharged during peak periods. These are financial plays optimizing Battery Energy Storage (BES) returns, different intents than energy resilience.

Setting Goals

"Energy Resilience" -- like the terms microgrid, block chain, and asset management -- is an exciting new term. What does it mean? What does it mean to you and your facility? EcoMotion works with a variety of clients that have different needs. There isn't one solution that fits all. Here are four design parameters to help customers clarify their goals:

Energy Resilience Design Parameters

[1] See EcoMotion's White Paper, "The Lithium and Hybrid-Electric Building Revolution," February 2016.

- Duration / Length of Resilience
- Loads to be Backed Up
- Carbon Intensity
- System Run Time

1. Duration / Length of Resilience: How long do you need to back-up? A day, two days? Seven days? Indefinitely? The longer the duration, the more costly the back-up solution.

2. Loads to be Backed Up: What do you need to back up? Critical loads only?[2] All loads? Even air conditioning? All are possible at price. It's just a matter of cost; an investment in resilience.

3. Carbon Intensity: Do you want a carbon-free solution? Consider the carbon intensity of resilient systems. What's your appetite for fossil fuels? Buying offsets can be bundled with conventional back-up systems to achieve carbon neutrality.

4. System Run Time: Closely related to Duration is System Run Time. Some energy-resilient systems – like emergency back-up generators -- are only used in emergencies, while others run continuously, like solar, fuel cells, and microturbines. If you are building a power plant, and if it's clean and cost effective to run, then why not run it all the time?

Addressing these parameters, this paper begins with the most basic resiliency options: Generators. Next are more advanced solutions including Microturbines and Fuel Cells. Battery solutions are presented as are Solar + Storage solutions, featuring six, carbon-free, fully financed microgrids developed by EcoMotion that can run indefinitely.

Pathways to Energy Resilience

This section presents five scenarios for resilience from the most basic to quite sophisticated. Basic in terms of cost and simplicity; sophisticated in terms of providing carbon-free operations indefinitely, while fully financed.

Without question, inarguably, the first step in any pursuit of resilience is efficiency. It's the least cost means of reducing your load, and to prepare for whatever back-up solution you choose. Make sure your lighting is fully up to date, that your HVAC is efficient and well-maintained, that plug loads are under control. There are a host of advanced energy-efficient technologies – Light Emitting Diode lamps, lighting and ventilation controls of all kinds, etc. – that can reduce loads at the least cost. In fact, for inefficient facilities, there is a unique opportunity to bundle efficiency with resiliency—wiping out the costs of resilience. We'll get into bundling later.

1. Generators

[2] The Code of Federal Regulations requires emergency back-up lighting for building occupants following the path of travel for egress. Such emergency back-up lighting – exempted for single family, two family, and rooming houses – requires two-hour emergency lighting at specific levels of illumination.

Generators have been around for a long time. These engines operate on diesel, natural gas, and propane. Some are V8 engines just like you'd have in your parents' Chevy. They are found in many hospitals, many supermarkets, as well as fire and police stations. They are work horses and are quite low cost. They have a reputation for being expensive to properly maintain.

Manufacturers of smaller systems include Generac (which makes 7.5, 9, 10, 11, 16, 20, and 27-kilowatt residential units), as well as Cummins, Kohler, Briggs and Stratton, and Norwell Power generators. Generators can be fixed in place, or portable.

2. Microturbines

Generators are a pretty basic technology: Fire 'em up and they generate electricity. Microturbines, on the other hand, represent a big advance. They're much like commercial aircraft engines; they generate electricity instead of thrust. Microturbines are the simplest form of gas turbine; they're also known as combustion turbines marked by a type of continuous combustion. Most are "single stage, radial flow devices," with rotation speeds of 90,000 – 120,000 rpm. Most use "recuperative" systems to capture waste heat from exhaust, boosting efficiencies.

Microturbines integrate aero-based turbine engines, magnetic generators, advanced power electronics, and patented air-bearing technology. They can be used for standby power, power quality and reliability, peak shaving, cogeneration, low cost power, and boost power. They cogenerate electricity and heat in the form of 50 – 80 degrees Celsius hot water. They are the simplest forms of gas turbines, generally 25 – 500 kW in size. They produce less noise than conventional generators which are reciprocating engines.

While providing energy resilience, microturbines can de-carbonize both electricity and space conditioning. They produce heat in the form of 50 – 80℃ hot water. Their efficiency can be as high as 80 – 90%, versus fuel cell efficiency of 50 - 60%. They can use a variety of gaseous and liquid fuels, including natural gas, hydrogen, kerosene, methane, propane, and diesel.

For large customers, microturbines can be engineered to tap into district heating and cooling loops. Microturbines can serve at the front-end of a system, augmenting or replacing operations conventional operations, or they can be distributed, located in buildings that benefit most. Capstone's installation at the Ronald Reagan Library in Simi Valley employs 16 microturbines that provide 960 kW of power, providing 95% of the facility's electricity requirement. The turbines' exhaust heat is captured for absorption chilling. A subset of the units is connected to the facility's heating loop.

Most microturbines today use natural gas for combustion. In the future, microturbines can also be a carbon-neutral option if run on biogas or hydrogen, or their use can be combined with carbon offsets.

The microturbine market is young: By 2016 there were approximately20 companies worldwide developing and commercializing the technology. Leaders include Bowman Power Systems from the United Kingdom, making an 80-kW unit. Others are Calnetix Technologies and Ansaldo Turbec with its 180 kW unit. Ingersoll Rand makes a 250 kW microturbine, the first in its size to be certified by the California Air Resources Board. While still a relatively nascent technology, microturbines have been deployed at wastewater treatment plants, agricultural facilities, landfills, oil production facilities, hospitals, and industries.

Capstone is Los Angeles based and a world leader in this space. Capstone claims to be, "The world's leading manufacturer of microturbine energy systems." Capstone products are supported by over 100 patents. The company's solutions are low emission and resilient, with scalable solutions from 30 kW to 10 MW. To date, Capstone has shipped more than 9,652 systems to 73 countries representing 953 MW of power capacity. By 2019, Capstone claims to have cut 350,000 tons of carbon emissions thanks to its installations. Capstone microturbines cost $780 – 1,100 / kilowatt.

Microturbines make sense in a number of applications. They work for public pools, schools, colleges, big box stores, jails, hotels, and manufacturing. The examples of Capstone's projects go on and on. The National Science Foundation Project in the Antarctica is powered by a Capstone microturbine, so is a green hotel in Jamaica – the Couples Tower Isle at Ocho Rios.

3. Fuel Cells

Fuel cells are an interesting and viable technology. Described simply as "continuous batteries," they have guaranteed production efficiencies for converting natural gas to electricity. Several chemistries are being deployed. Bloom Energy states that its solid oxide fuel cells operate like baseload power plants and result in less costs and net greenhouse gas reductions compared to grid power.

Bloom Energy is currently the leading fuel cell provider, offering clients 10 – 15-year contracts and an attractive no-money-down business proposition. It has been highly successful at selling its economic solution to big box stores and others. Its natural gas fuel cells have been installed throughout California. In the future, these fuel cells will run on renewable natural gas and ultimately hydrogen, providing carbon-free generation.

Bloom argues persuasively that right now its fuel cell emissions are lower than solar since fuel cells are baseload and deliver 24*7 savings. Solar, on the other hand, has to be backed up with non-renewables. The combined emissions of solar, plus its carbon-based back-up, are greater than the fuel cells. Fuel cells operate all night long when there are limited renewables on the grid, and thus the carbon offset is significant.

There are two cost components of Bloom's fuel cells. With the first component, there is no upfront cost for the equipment. Instead, customers pay a "tolling" rate equivalent to $0.10/kWh for use of the fuel cell equipment installed. Given LADWP's prohibition of Power Purchase Agreements (PPAs), Bloom developed an "Energy Server Use Agreement" for the sale of MMBTU of energy at its sites. Bloom charges LADWP customers $/MMBTU versus $/kWh.

The second cost component involves the purchase of natural gas. Customers buy their own natural gas. Customers work with gas providers to lock in favorable gas prices. Bloom's gas specialists are on hand to advise clients as to whether they ought to float with the market, buy an option of 50% hedge, or engage in other strategies.

When these two cost components are combined, Bloom's fuel cells generate power for ~$0.13/kWh, providing suitable customers with savings of $0.03 – 0.04/kWh. Often Bloom will pair its fuel cells with energy storage in the form of advanced batteries.

Once a generator of any kind is installed in the LADWP system that exceeds 1 MW, the rate automatically shifts to the cogeneration rate with low NEM values. This means that power exported to the grid from fuel cells would reap a value far less than the retail value of power. While rate structures vary, fuel cells are generally sized for baseload needs, providing deep levels of energy resiliency when in back-up mode.

The LMU Case Study

In 2019, EcoMotion was retained by Loyola Marymount University to assess its renewable energy options. We developed four pathways for smart energy management at LMU, beginning with energy efficiency upgrades.

The optimal scenario maxed out the rooftop/NEM solar potential – connecting 1 MW of solar to each of the two meters on campus – then added 3 MW of feed in tariff solar. But what was really interesting were the options that considered fuel cells and microturbines, both of which could add resiliency to the campus.

Fuel cells would provide baseload capacity, providing deep savings and net carbon reductions for the next 10 years. Microturbines can follow demand, and thus offer greater flexibility. They also provide hot water that can be used on campus for space and water heating, and potentially absorbent chilling.

What began as a solar investigation at LMU, blossomed into a broader evaluation of distributed energy resources and how to maximize savings, carbon mitigation, and energy resilience.

4. Batteries Alone

Powerwalls and other residential battery systems provide homeowners with a modicum of resilience. For a price, you get a set number of kWh of battery capacity. It's not much—the capacity that is. LG makes a 9 kWh battery for homes; the Sonnen ecoLinx battery is 12 – 20 kWh depending on its configuration. It boasts an automatic transfer time of less than 100 milliseconds. That compares highly favorably with a typical generator start times of 5 – 10 seconds.

Powerwalls bear a high price, but there are some clear advantages of battery back-up solutions. They monitor the electric feed from the utility and automatically take over when the grid goes down. There is no combustion and no noise. Batteries are "lab-coat-clean operations," providing energy arbitrage values throughout the year.

Batteries can be programmed for different scenarios. Powerwalls allow owners to program their batteries in four different modes:

1. Back-Up Only: Battery sits there full until the grid goes down
2. Self-Powered: Battery stores excess solar power for night-time and rainy-day use
3. Balanced Time-Based Control: Battery stores solar power for use at peak times
4. Cost Saving Time-Based Control: Battery used to maximize economic savings

Pricing continues to evolve: Tesla Powerwalls for residential sized loads currently cost ~$437 / kWh, down from $469 for the first generation of Powerwalls. Tesla Powerpacks for commercial clients are sized at 100 and 200 kWh, with costs of $470 and $398 / kWh respectively.

5. Solar + Storage

In EcoMotion's opinion, the ultimate option is to pair solar with batteries and to create microgrids in the event of a power outage. When paired with solar, batteries are eligible for the federal investment tax credit. In combination, consumers can operate silently and, in a carbon,-free mode.[3]

<u>Santa Rita Union School District</u>: Imagine a small school district in Monterey County, Salinas to be precise. There, in early 2019, the six campus, carbon-free microgrid project EcoMotion developed was interconnected and given permission to operate. With solar systems installed on each campus to cover 100% of the load, plus seven-hour battery capabilities and sophisticated energy management controls, now each campus is designed to island from the grid using a combination of solar, storage, and controls.[4]

The financial beauty of these microgrids is that their components are working daily,not standing by waiting for the infrequent calamity. By generating solar, storing excess solar, and discharging batteries at peak periods, the resilient systems are flexed daily. Being tied to the grid strengthens their economics. In fact, it is the savings that the solar system generates that effectively pays for the costly batteries that are infrequently used. (In other cases, energy efficiency gains can be coupled with batteries,using the highly favorable economics of efficiency to pay for the highest cost of storage.)

The Santa Rita schools' resilient systems are designed to operate indefinitely in a carbon-free mode and prolonged outage. The systems were financed by Generate Capital "at parity," meaning that the annual cost to finance and pay for the microgrids is the same as the District's prior annual utility cost. This project won a Microgrid Knowledge award in 2019 and serves as a

[3] See EcoMotion's Podcast, EcoMotion Conversations, with Jigar Shah, CEO, Generate Capital, May 4, 2018.
[4] See EcoMotion's White Paper, "Creating and Financing Six, Carbon-Free Microgrids for Santa Rita Union School District, September 2018.

model of campus resilience.[5]

Vehicle to Grid Technology: Any even more sophisticated smart energy management solution may well incorporate vehicle-to-grid (V2G) technology. Imagine a school district with electric buses. Each of these has 100 – 150 kWh of battery energy storage. With V2G capability, a bus or two could be deployed to a campus that is dark, plugged in to power the campus through the outage. School bus fleets can be used to provide demand response services for utilities, and ancillary services for grids, representing secondary and tertiary revenue streams for the batteries that can result in the utilization of costly assets.

Microgrids: What Scale, What Fuel?

This past fire season was catastrophic for California utilities and for their customers. PG&E shut down nearly a million customers during 2019 fire season through its Public Safety Power Shutdown (PSPS) program. No one was happy. Customers have responded by installing their own generators, batteries, and solar + storage combinations. In fact, 7,800 PG&E customers have already installed 118 MW of battery energy storage systems. Another 4,300 signed up to interconnect solar + storage systems in 2019. They aren't waiting for utility solutions.

There's a debate in California about the right role for microgrids to foster resilience. What scale ought they be deployed? Should the approach be top-down, or bottom-up? Bottom-up solutions are at customer sites. Top-down solutions are being proposed by PG&E at the substation level. PG&E has committed $1 billion for 20 substation microgrids with a combined capacity of 500 MW. It hopes that select developers will build microgrids in time for the 2020 fire season to provide energy resilience to its customers, a timeline that many think is unrealistic. PG&E plans another 28 in 2021.

While California is "a vortex of microgrid activity," and the PG&E $1 billion solicitation will represent 10% of the global microgrid market this year, some microgrid developers are sitting on the sidelines of the PG&E solicitation. First off, PG&E is working its way out of bankruptcy. Second, customer demand for energy resilience is where the action is. Third, many microgrid developers and advocates are fighting against fossil-fueled microgrids.

Aren't fossils the fuels largely responsible for the climate crisis in the first place? Some distributed generation proponents such at Caterpillar, Tecogen, and Solar Turbines advocate the use of fossil fuels in the short term to support this massive deployment of microgrids. In response to overwhelming testimony at the CPUC, PG&E is exploring the procurement of renewable natural gas to power its microgrids.

Our House: A Microcosm

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[5] See also EcoMotion's video on the Santa Rita Union School District microgrid project. It's titled, "Microgrids, Energy Resilience, PERCs" and can be found at: https://youtu.be/82a1mRV3lTk

As EcoMotion gets deeper into providing energy resilience services to our clients, I began to consider my own home in Glendale, California. It's not currently an example of energy resilience. We installed a 7.9 kW DC solar system a few years ago. Since we sized it, we added a split system for our AIRBNB unit, and an electric vehicle (EV). We'll likely add a second EV soon; we already need to add more capacity to our solar system.

But for now, we're considering resilience because if the Glendale Water and Power grid goes down, we'll have nothing more than the frustration of a solar power generator on site that we can't access in emergencies.[6] We don't need to back up our biggest load – air conditioning. We would, however,like to be able to maintain a cool fridge, to provide basic lighting and security, to be able to charge our phones, and to maintain communications through internet, TV, and radio for as long as need be.

<u>Powerwalls</u>: Welcome a really energetic salesman from Semper Solar, a veteran-owned business that sells Tesla Powerwalls. For about $15,000 we can get 13.5 kWh of storage;That's not much back-up power. Our average daily use is 35 kWh. Thus, a Powerwall would only back up critical loads such as our refrigerator, the coffee maker, and cell phone charging through the night. Then the battery would be recharged with solar the next day.

In addition to the resilience benefit, the Powerwalls, like other storage units, do provide a revenue stream, albeit small, through "energy arbitrage." The batteries can be charged during off-peak periods, and then discharged at peak periods, offsetting higher rates.

<u>Generators</u>: Our next visitor was a seasoned salesman named Jeff from Elite Generators. For about $10,000 I can buy a 22 kW Generac generator that would run on natural gas, and which would power the entire home for as long as I need the back-up. No skimping in this model. We'd have huge amounts of electricity—easily enough for full air conditioning and charging the EVs. We'd be the beacon of light in the neighborhood!

What if the gas system is not delivering natural gas to power the generator? Natural gas systems reportedly fail only 5% as often as electricity grids. Furthermore, Generacs' air-cooled units (residential) can change fuels from natural gas to propane at the flip of a switch. Elite sells propane tanks to back-up the back-up generators' fuel supplies. The size propane tank that I like would run the engine for 55 hours.

I was curious about part-load conditions: What happens if we are not using 22 kW of power on site at any given time? In fact, we never would use that much! I was told that the generator maintains its 3,600-rpm requirement, but produces less power to meet the demand. Think of a car going uphill: When the terrain flattens out, the engine eases off while maintaining a steady speed. An engine has to work harder going uphill to maintain the same speed as it does on the flat. Inversely, a generator can ease off when the load that it is serving drops off.

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[6] There are inverters available for homes that do offer a modicum of energy resilience. Sunny Boy inverters, as well as Outback inverters, provide 1.5 kW of AC power in the event of a grid outage. While a fraction of a total solar system output, this is enough power for the most critical loads... things like cell phone charging and keeping beer cold in the fridge!

Elite represents Generac units up to 150 kW in size. They typically size generators at half the household amperage. Jeff recommended that we work with 200 amps for our sizing, thus the 22 kW unit that generates 100 amps. Generac makes air-cooled units up to 48 kW in size. Jeff did say that “they are a bit noisy,” about 66 decibels at 10 feet. Salesmen claim this is about the same sound intensity as a phone ringing. Larger units are water cooled, making them quieter but also more costly.

I ask about carbon emissions from the generators. Stunned I am: Jeff says that this is the first time he’s fielded that question. He comes up with the answer I’d give if I were in his shoes: Generators’ emissions are based on very short run times. Outages, thankfully, are infrequent and generally short. Furthermore, natural gas is the cleanest of the fossil fuels, once considered “the prince of hydrocarbons.” Generators do require “exercising” for about five minutes every month, but this generates few emissions. They’re fully approved by the South Coast Air Quality Management District. So “no big deal” was the gist of his response to my concerns about carbon.

Vehicle-to-Grid (V2G): So far, I have not jumped. While the Testa Powerwall appeals for a number of reasons, its amount of energy stored really does not amount to much. While the generator option is less expensive and provides robust power output, it is based on burning the very fuels that are responsible for the climate crisis that has led us to energy resilience in the first place. So, what to do?

The ultimate answer may be in my driveway in the form of an electric vehicle. My Chevy Bolt has a 60 kWh battery pack on board, four times the Tesla Powerwall’s energy storage. While I cannot use that energy yet, “vehicle to grid” integration is coming. Soon I will be able to use my car as a battery back-up system. By installing a bidirectional inverter, I can draw power from the car, or charge it up with solar or grid power.

In this future scenario, my mobility becomes the tool to provide household resiliency. This is coming; I’d give it 3 – 4 years before it is common. In the meantime, I plan to a) add more solar panels to cover 100% of my household consumption, and while we’re at it and needing additional inverter capacity, we plan to b) install at least one Sonny Boy inverter with a 1.5 kW emergency capability.

Conclusions

The pursuit of energy resilience is real and growing. More customers are seeking emergency back-up solutions. The most basic solutions are available and can easily be implemented. More sophisticated carbon-free solutions exist that, if properly aligned, can provide savings.

At EcoMotion, we promote win-win solutions: solutions that make sense economically and that make sense for the environment. We caution that traditional generators are part of the global climate crisis we live in today. Burning more fossil fuels in the name of energy resilience is like shuffling deck chairs on the Titanic. Yes, they can be consciously employed with offsets, but our strategic team is looking to finance new, high-tech solutions that provide multiple benefits without gross trade-offs.

In some cases, generators will be used. In other cases, microturbines will be employed given their high levels of thermodynamic efficiency. Fuel cells are another option depending on load profiles. We gravitate, of course, to solar and storage solutions that are carbon free, that represent the new grids of the future, and fully integrated with mobility and e-bus battery system. Microgrids one day will be managed with block chain accounting, providing clean and local energy, local economic development, and heightened levels of energy resilience.