SUPPORTING COMMUNITY RESILIENCE: SUMMARY OF THE STATE OF PROSUMER ENERGY STORAGE SOLUTIONS

The reasons to install home and single-premises energy storage, especially when paired with rooftop solar, have recently become overwhelmingly compelling in Colorado despite many changes at the federal level. Producer-consumer, or "prosumer," owners of such distributed energy resources have seen payback periods on their investments reduced based on new time-of-use billing savings. Shorter payback may also be possible depending on what value the prosumer owner may place on resilience due to damages from outages. The emergence of virtual power plants, or aggregations of these resources, improves the value further. For those looking to improve their resilience in the face of increasing outage durations due to extreme weather events, the value proposition of adding bidirectional charging for vehicle-to-home (or vehicle-to-building) surpasses even gas backup. Moreover, ***reducing the load on the grid and providing stabilizing grid services near those loads, can improve quality of service and save all grid participants money versus traditional grid investments****. Lithium-ion battery technologies, because of their dominance in electric vehicle applications and rapidly lowering costs from an emerging host of U.S. manufacturers, will continue to be the dominant home and single-premises energy storage solution for at least the next ten years.* — James Gilbert, 30 July 2025

THE COMPELLING CASE FOR "PROSUMER" OWNERSHIP OF HOME AND SINGLE-PREMISES ENERGY STORAGE

It is not news that distributed energy resources like rooftop solar and storage have offered the promise of "energy independence" for some time in the U.S. and the world, including Colorado. Indeed, the looming fruition of that vision of an affordable, flexible, resilient and emissions pollution-free grid for everyone seems tantalizingly close. While affordable rooftop solar (PV) has seen dramatic gains elsewhere around the world, the U.S. has recently lagged and possibly even plateaued in home and single-premises PV installation growth. Enter: batteries.

This plateau in solar for the U.S. has occurred because the combination of net metering (NEM), higher import tariffs, and higher soft costs (e.g., permitting, install services, etc.), and longer installation timelines, than most other countries, has led to higher costs for building owners and inequity for non-solar ratepayers in the U.S. The cost for installed solar in the U.S., for example, is over three times that of Australia, where most of these problems have been solved. This situation has been further complicated by the counterintuitive and counterproductive thesis that the grid has to expand to accommodate unorchestrated excess solar that may not get used, instead of orchestrating via curtailment.

Utility regulators around the country, and most notably in California and recently in Colorado, have had to change from net metering policies to net billing tariffs (NBT) with time-of-use (TOU) rates to be more reflective of the market value of the unorchestrated excess solar in time and location. The new Colorado TOU rates due to start in November of 2025 are such that home solar sent to the grid will see much reduced value. Regulators around the country have also begun to open up and require orchestration of these resources to put them to more efficient use through demand response programs and their more sophisticated younger sibling, virtual power plants.

Virtual power plants are aggregations of real-time orchestrated distributed energy resources, where prosumer owners can make choices about their level of participation, while their aggregators in turn are compensated for only the services provided to the grid. This is instead of the typical feature of demand response programs, which have generally unsustainable levels of up front incentives to join, coupled with blanket monthly participation compensation that may be

SUMMARY OF THE STATE OF PROSUMER ENERGY STORAGE SOLUTIONS Continued

unrelated to the services actually rendered, as these are both ultimately paid for by all rate payers.

Despite what sounds like bad news for solar, then, is actually good news in the combination with storage, as this situation has led to a rapid explosion in adoption of the pairing of storage with solar, and in particular distributed home and single-premises energy storage solutions (ESS). Perhaps even more exciting have been the developments in **bidirectional charging, or vehicle to home or building (V2H, V2B) technologies**, that allow electric vehicle batteries to be utilized as auxiliary storage for not only savings on net billing time-of-use but the added resilience of enduring longer grid outages during the ever increasing frequency of extreme weather events.

While the dream of going completely "off-grid" with such solutions is still impractical for most, the break-even point for even just the average case of offsetting net billing time-of-use has come down with proper system sizing and smart home technologies. In places subject to long-duration outages, when paired with V2H/B, this has become an even more mobile, affordable, and clean solution than investing in and maintaining backup gas generators with fuel on-hand. This can be crucial in deciding on batteries for many of us in Boulder. In 2024 many Boulder residents experienced up to 700 minutes (11.6 hours) of outages each year. Some on the order of days each year.

Moreover, as virtual power plants come on line that promise to compensate prosumer owners of these distributed energy resources for other grid services beyond simply sharing their excess energy, the value proposition gets even better to fully participate as active co-investors in their own community's cleaner and more stable grid. The bonus being higher grid reliability and resiliency, as well as avoiding more costly traditional investments in the grid, such as gas peakers that would otherwise be required to provide extra energy on a hot day. That means prosumers save money to the affordable benefit of all grid participants.

Prosumers save money to the affordable benefit of all grid participants.

Exploring the grid benefits further, storage paired with renewable sources is a multiplier of the reliability and resilience of those sources. It not only provides clean energy backup when the wind is not blowing or the sun is not shining, but can provide necessary balancing, stabilization, and flexibility services when grid loads and sources suddenly change. While storage at remote utility-scale source sites can provide those services to the transmission side of the grid, storage on the distribution side, where homes and businesses are connected, can likewise provide these stabilization and flexibility services to improve quality of service, supply peak loads, and even absorb some of that peak sun from solar panels right at the loads. More and more utilities are recognizing the need for these services and providing incentives to storage prosumers, be it their wall battery or EV, through new battery demand management and virtual power plant programs like Xcel Energy's Battery Connect program in Colorado.

HOW TO GET STARTED IN THE BOULDER AREA?

First, if you haven't already, get an energy audit and electrification consult like those available through Boulder's Energy Smart program. These are currently offered for a modest fee to most Boulder residents, but if you are income qualified, they may be free. Be prepared to share with them your electricity usage information from Xcel, and whatever backing information your smart home sensors might be able to provide, if you have them. Look at making as many efficiency upgrades to your home energy usage as possible, like adding insulation, or sealing those old leaky windows. Check out any recommendations your auditor may have on upgrading old appliances to newer, more efficient, smart home appliances. The difference for instance between a 20-year old drier and a new one in energy savings may surprise you.

Then get a solar plus storage system quote from your local installer, like those available through Boulder County's Switch Together program. Switch Together

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offers lower prices as it makes group purchases. They will also help you through the process of getting rebates and joining new programs like Xcel's Battery Connect, or other demand response and virtual power plant programs available in the Boulder area.

When you are looking at storage for back-up, you will need to decide what circuits or things that you must have power for during an outage. This is called identifying your "critical loads." For instance, obviously, you need your refrigerator, but do you really need that extra wide-screen TV on? Tell your installer that you want to optimize your time-of-use savings, but still have some resilience time for backup of critical loads during extended outages. As bidirectional charging is such a new technology, it may come as a surprise, even to savvy installers, that reducing your battery size to handle shorter time-of-use savings and augmenting resilience with vehicle-to-home to handle those longer outages may make more sense than buying a much larger battery. Make sure that the installer is familiar with the configuration requirements for doing this and that your electric vehicle is vehicle-to-home ready and compatible.

Your electric vehicle may also have vehicle-to-load with outlets you can use for emergency backup.

If a home battery system is still too expensive, you may wish to investigate smaller, uninterruptible backup systems on select loads like your refrigerator and medical devices. Your electric vehicle may also have vehicle-to-load with outlets you can use for emergency backup. Ask your energy auditor and installer about these options, too. You may be surprised how well even such modest devices like these may work for your needs in critical situations.

LITHIUM-ION TECHNOLOGIES WILL CONTINUE TO DOMINATE THE HOME ENERGY STORAGE MARKET

For would-be home and single-premises energy storage prosumer investors the dominant energy storage solution today relies upon lithium-ion battery technology. Indeed, the U.S. is poised to go all-in on lithium-ion battery technology with the opening of many new battery manufacturing plants and their supporting technologies. Prices, even with tariffs, will no doubt begin to drop precipitously relative to other technologies, as supply increases from a host of domestic manufacturers over the next several years.

For those uncomfortable with the most popular lithium-ion solutions and their relatively small potential for overheating and fires, there are not a lot of other choices that are actually available at the same technology readiness level (TRL) of 9/9 like Tesla's Powerwall, or at affordable price and realistic size. For example, while there are some newly arriving offshoot solutions using the more inert **lithium-iron-phosphate (LiFePO)** technology, these are typically significantly more expensive and only available from a precious few suppliers. Despite the higher price, its inert qualities, high density, and high cycle rates make lithium-iron-phosphate a tantalizing choice for utility-scale energy storage. Meanwhile, more established technologies such as lead-acid are typically only sufficient for very small electrical load footprints, or with plenty of space to put the large number of cells required. It is unfortunate that Aquion's once-promising **saltwater batteries** went away and their cousin-tech **sodium-ion** seems perpetually unready for commercialization.

EV's account for over 98% of the battery market, therefore, they drive the battery tech development overall. Almost all the research and development money in battery tech today is going into improving lithium-ion batteries and its variants, including the much touted solid-state batteries. This assures that lithium itself will likely remain the dominant source material for batteries for the next ten years or so, at least.

THE LITHIUM-ION HOME BATTERY ALTERNATIVE FRONT-RUNNERS

If those investors in home battery loathe to any lithium are willing to wait another year or so, however, there

may be a better, competitive, alternative that is less-expensive (and exotic) than the recently popularized **vanadium redox technology**, or even LiFePO. This battery technology is called **manganese-metal-oxide** and uses a non-toxic water-based electrolyte. It is in field testing for grid storage now, has 5x-10x the energy density of most redox flow batteries, but should be available soon for home storage batteries from Alsym Energy. This is probably what most would call a technology readiness level of 7/9 or 8/9.

Redox flow batteries, like Storen's, a leading developer in redox flow, have great potential for cheap and safe stationary storage, especially for grid storage. But the tech is not typically considered good for EV or consumer use because it has much lower energy density than most other tech. That means it takes up a lot of space. It is also not quite a fully mature tech as it has been tested, so maybe a TRL 8/9, but is not yet in volume production with wide commercial deployment, let alone non-utility-scale storage applications.

The U.S. military for its part is keen on a higher energy-density version of flow batteries called **nanoelectricfuel (NEF) batteries**. They would prefer to use a technology like NEF as the basis for all batteries, e.g., EVs, equipment, storage, etc., in the field. Imagine going to a NEF station of the future: a pump draws out your spent fuel to recharge it and replaces it with freshly charged fuel– all in the same time it takes to go to a gas pump. It looks like Influit, the primary developer of this technology, is pretty far along on their readiness with potential for first field test deployment before 2030, given the right amount of investment, but I would estimate it is no more than a TRL of 5/9 or 6/9. There simply aren't a lot of non-military investors, yet. That could change, if they start getting deployed by the U.S. military.

Graphene is no doubt a fast up and comer in the EV market that is favored to replace lithium-ion batteries in EV's by sometime in the early 2030's before solid-state batteries, even. However, they are still at a relatively early stage in their tech development at a readiness level of 4/9.

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