



Graphene Battery/Supercapacitor ESS

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As of this writing, the world's demand for large utility-scale energy storage systems, commonly referred to as **ESS**, cannot be fulfilled by the current ESS batteries on the market. What is that demand? Why is there a demand? And what is the problem with the battery industry keeping up with the demand? What is the outlook in the coming years? And what is Qpacity's role in the ESS market? We will answer all these questions in this paper.

Most people know by now that most of the electrical grid infrastructures throughout the world are old and failing.¹ The actor, Dennis Quaid, hosts a recent documentary entitled, "Grid Down, Power Up."² As so succinctly explained in the film, and backed up with evidence, not only is the U.S. infrastructure old, outdated and failing, it could be fixed for less than \$50 Billion. There has been ample opportunity, money, and resources to do just that for several decades. Since there is such a huge push to go electric in nearly everything, especially cars and trucks, a new burden is being mounted, not only on the grid itself, but the ability to produce enough energy.

Thus, we now have a demand in, not only the U.S., but throughout the entire world, to create energy storage solutions as utility grid "backup" for the purpose of providing energy at peak times. These systems are generically labeled Energy Storage Systems, or "ESS." While a battery of any size could surely have that label, the industry has reserved it for massive systems, usually from 500 kilowatt-hours (kWh) to 5,000kWh per unit (5,000 kWh is the same as 5 megawatt-hours or 5MWh). Compare that to a typical household solar power storage battery of 5-15kWh.

ESS batteries are also in high demand for micro-grids and "off-grid" solar and wind systems that need their generated power to be stored for a utility grid or for end use demand.

The Demand is Great

There have been many published forecasts of the huge need for utility-scale ESS in the coming years. It appears there is no single consensus on that number. Tesla sells an ESS unit called *Megapack*. Those are currently sold as 1.9MW units with 3.9 MWh energy capacity. Tesla is able to produce 10,000 *Megapacks* (total of 39,000 MWh or 39 GWh (gigawatt-hours)) per year³ and they currently have a 2-year backlog on orders.⁴ The overall industry consensus is that worldwide energy-storage demands will be in a 1-2.5 Terawatt-hour range. Which is a huge number to contemplate when it comes to building batteries to contain that amount of energy.⁵ A large percentage of that growth is based on the expected surge in electric vehicles.⁶

Current ESS Production Efforts

There are many other competitors that have entered the ESS marketplace besides Tesla, although Tesla is the largest. Most cannot produce even 1 GWh in a year compared to Tesla's current 40 GWh of annual production. The point being, production is still not keeping up with demand, which is growing exponentially.

A Huge Problem Lurking

It all sounds wonderful: the plan to go “green” and use renewable resources such as wind and solar and to be able to store that energy in batteries and even backup the grid, so forth and so on. However, news has been getting out in recent years of the dangers of lithium batteries. The rate at which there are “thermal runaway” incidents being reported is increasing rapidly. It’s not just mobile phone batteries bursting into flames that we hear about anymore. Now we are hearing of car batteries, home wall batteries (used for storing solar energy) and even the large utility-scale ESS units, overheating (known as thermal runaway), exploding, and burning at such an intense rate that its nearly impossible to extinguish. This happened recently with one of Tesla’s *Megapack* ESS units in California. It happened at a PG&E Substation in Monterey, California on September 20, 2022. It was serious enough to cause road closures and residential shelter-in-place orders.⁷ This was not the first or the last.

South Korea has had bad experiences with Lithium ESS units. 23 burned during a one-year period in 2018. More recently, there were 7 ESS fires reported over a two-year period ending May 2022. The fires were investigated by Moon Seung-ill, a professor at Seoul National University’s Electric Power Research Institute. The research showed that either a thermal runaway of the battery cell or an electrical leakage to the ground was witnessed as the fire broke out in a battery cell.⁸ The South Korean government has cracked down on ESS, calling for better safety measures.

The industry is experimenting with Lithium hybrid batteries in attempt to curtail the dangers. In some cases, progress has been made, but the cost usually means less dense energy cells and a sacrifice of performance. For example, limiting the battery charge to something less than 100%, maintaining a slower charging rate, and discharging slower and to a lesser extent. All these limitations create a higher cost per watt-hour when a battery cannot be fully used.

Cycle Limitation of Lithium Batteries

Like any battery, even the lithium and lithium-ion batteries have a limited life. This is mostly due to a limited number of times it can be charged and discharged, called a “cycle.” While lithium made a great improvement of cycle life over traditional lead-acid batteries and Ni-Cad batteries, it still has a useful life that must be factored into a true cost of watt-hours of storage over time. (It is very difficult to find information on Tesla and other manufacturers on the expected cycle life of their ESS units. They have nothing to brag about in this area, so it stands to reason they prefer to hide it.)

Not only are the batteries limited as to their life of charging/discharging cycles, but the extent to which the battery can be fully charged in a reasonable time and the extent of discharge. This is called Depth of Discharge (DoD). Most batteries, including lithium, do not do well with 100% discharge. And, due to overheating problems it has been suggested not to charge to 100%.

Toxic Waste from Lithium

What happens at the end of a lithium battery life? The contents of those batteries are considered toxic to the environment. Tesla says they can reclaim about 50% of the lithium and “recycle” the battery, but where is the other 50% going to be dumped? Eventually, even the second round of recycled lithium must be discarded. This presents a serious future toxic waste issue. “Currently, there are no universal or unified standards for waste disposal of [lithium-ion batteries] around the globe,” as indicated by

Wojciech Mrozik and three of his colleagues in the co-authored article published in the Energy & Environmental Science journal. They went on to say:

The evidence ... from real-life incidents ... shows that improper or careless processing and disposal of spent batteries leads to contamination of the soil, water, and air. The toxicity of the battery material is a direct threat to organisms on various trophic levels as well as direct threats to human health. Identified pollution pathways are *via* leaching, disintegration and degradation of the batteries, however violent incidents such as fires and explosions are also significant.⁹

Other Technologies Attempting to Resolve Lithium Battery Dangers

Some companies are developing “redox flow” batteries as an alternative to lithium. Because of the liquid requirements, this technology is only practical in large scale applications, such as in the ESS industry. The two primary reasons it has gained some support is the reduced risk of thermal runaway and better battery longevity. Some manufacturers are touting the potential of a 20,000+ cycle life. That is definitely impressive and something that is needed to reduce the end-of-life waste concerns.

However, with those advantages come many problems and disadvantages. Depending on the chemical formula a manufacturer is using, some use rare earth minerals that are difficult to obtain as well as costly. There is also the factor that liquid (water mixed with various metals, minerals or compounds) is being pumped through the battery system and is usually very acidic, giving rise to potential corrosion. Pump systems add to the complexity, maintenance, and greater risk of breakdown due to moving parts. Perhaps one of the biggest disadvantages is the low “energy density.” Any given amount of material in a battery cell or storage system can hold only a finite amount of energy. Naturally, the goal for any technology is to achieve the highest possible energy density. This saves space, weight, and cost. Lithium-Ion batteries have an average 250 watt-hours per kilogram (250 Wh/kg) whereas redox flow batteries are only 15-30 Wh/kg. To achieve the same energy storage as a Lithium-Ion ESS, a redox flow battery will need to have 8-16 times more volume and considerably more weight.

There Must Be Another Solution

For several years scientists and engineers have been looking to graphene, a two-dimensional form of crystalline carbon, to solve the world’s battery problems. It is known that graphene has a very high energy density, is a renewable resource that can even be extracted from plants, is non-toxic to the environment (so no special waste dumping protocols needed), will not overheat, very long potential life (very little degradation over time, if any), and will not ignite (eliminating explosion and fire issues). With all those wonderful characteristics why haven’t we seen graphene batteries on the market replacing all of the problematic batteries? Simply put, the universities and big labs in the world that are being looked to for the answers have not figured out how to make the graphene otherwise function like a normal battery.

We are not going to use this space to explain all the ways in which those engineers’ and scientists’ attempts have failed, since there is ONE graphene battery that has proven to be successful. That’s the battery for which the remaining of this paper will devote its space.

The Graphene Breakthrough

Our team at Qpacity discovered the graphene battery technology through one inventor. His batteries had been on the market for over 5 years when we discovered it. How could a small one-man inventor figure out what all the combined universities and energy labs in the world have yet to discover? As he put's it, "they are looking in the wrong direction." He indicates the solution to the graphene problem is not in the ingredients (many are trying to use graphene with other substances in attempt to make it work), but it's in the manufacturing "process." He has kept that a trade secret rather than patenting it. His technology has been proven though many different applications and sizes, from golf cart batteries to home solar batteries to shipping container size ESS batteries supporting utility grids. Qpacity is now in the position to take this technology to the world in a large way.

One of the breakthroughs that makes our battery so superior is it is built as a supercapacitor, with the ability to take a charge as if from a 'fire hose' and discharge as rapidly as needed too. It can go through literally limitless cycles. These are known characteristics of capacitors. However, it is also known that capacitors (or supercapacitors too) traditionally cannot be used to store energy for long periods or allow slow discharge of energy. Our graphene supercapacitor has solved those issues, making it function like both capacitor AND battery. No other technology in the world has achieved this capability.

The Qpacity Graphene Supercapacitor/Battery ESS Characteristics

Non-Toxic and Non-Flammable: Our batteries are non-chemical based. Graphene is the main ingredient and presents zero toxicity if put into any waste facility, such as landfills. There is no acid to be concerned with or that will cause corrosion. There is ***nothing in the Qpacity battery that will overheat, catch fire, or explode even if penetrated or put near extreme heat.*** Unlike lithium batteries, ***our batteries are certified to be transported on aircraft and in closed spaces.***

Operates in Extreme Temperatures: Our batteries will function down to minus 40 degrees Celsius/Fahrenheit and as high as 70°C (158°F). These very high or low temperatures do not effect charging or discharging. There is no other battery in the world like this.

More Cycles: Our batteries can go through more charge/discharge cycles than any battery in existence. This is due to the supercapacitor aspect of our batteries. ***Our batteries will go through tens of thousands of cycles, perhaps even into the millions.*** (A current life cycle test underway has a battery with over 1,000,000 cycles and still going strong.) Compare that to other batteries. For example, a typical automotive lead acid battery will last a few hundred to a maximum of 1,000 cycles. Tesla's EV battery warranty accounts for only 1,500 cycles. Their home *Powerwall* through their huge *Megapack* ESS batteries is only expected to last 4-6,000 cycles, having a 3,200-cycle warranty. We warranty our batteries for a minimum of 20,000 cycles.

Deep Cycling / DoD: Depth of Discharge (DoD) is a big concern in the battery industry. Most know that lead acid batteries cannot be discharged 100% without damage. In fact, most recommend not discharging more than 50% of capacity. Lithium batteries can have a greater DoD, but seldom to 100%. Typical is 80-90%. Often this is hard to control and at least a nuisance. ***Our batteries do not lose longevity or have a need for deep cycling or shallow cycling to increase longevity. It matters not to what level our battery is charged or discharged.*** Since 100% of our battery's capacity is useable, we can apply a smaller size battery than a competitor's for the same application.



Charging Time: Most batteries need to be charged at a relatively slow rate. Especially when the desire is to provide the maximum charge a battery can take. There have been some advances in this area, but even so, once a battery reaches 80% capacity the charging must slow to a trickle to avoid overheating. The battery industry can be a bit deceptive with their advertising when they make charging time claims. The claim they typically make is the time it takes for a charge to 80%. The last 20% can take many hours even days as compared to perhaps 30 minutes to 4 hours for 80%. In addition, the traditional batteries (lead, nicad, lithium, etc.) can easily become overheated when attempting to charge too fast. ***Our batteries can take a charge as fast as there is power available. In other words, a “firehose” of electricity can charge it, at a super speed, and without any heating. This method can occur all the way to 100% charge.*** No other battery can claim that advantage. Note: Our ESS batteries (sized from 1 to 5 MW) can fully cycle (complete discharge though complete charge) at least 4 times more in a 24-hour period than any competitor ESS. Charging and discharging can also take place simultaneously at full rate. No other battery in the world can make that claim.

Discharging Rate: Discharging most batteries too fast or too deep can damage the battery. ***The Qpacity battery can be discharged all the way to zero and the power can be used or drained from it as fast or slow as needed.*** Fast discharge is one of the characteristics of supercapacitors. However, the Qpacity battery can also allow very slow discharge, which is not an ordinary function of capacitors. Our battery does not suffer from the ***bell curve*** phenomenon where voltage is decreased as the battery gets closer to empty. The available voltage remains the same all the way to 100% discharge.

Imagine a battery of any size and application outperforming any other battery in the industry, lasting longer than any other battery, having a proven safety record like no other and completely non-toxic in the event of battery discard.

The environmentalists love our batteries. Not only are they non-toxic while operating and at the end of life, but they also last for so many years few will be discarded. There is NO landfill or dumping concerns as there is with lithium and other chemical batteries.

Qpacity ESS (Energy Storage System) for large commercial applications: There are two types of ESS. One is strictly energy storage. These are most often used as a utility company’s backup energy for the grid. There is also a “smart” ESS that is used to accept power produced off-grid (e.g., solar, wind, water, etc.) and deliver the energy to end users. These ESS have controllers, inverters, etc. A Smart ESS often will have numerous storage-only ESS units based on demand needs. The ESS batteries are not only used for utility grid backup but also micro-grids (on or off-grid), large commercial and industrial applications such as hospitals, factories, warehouses, crypto mining operations, and small community micro-utility. (See Qpacity ESS spec sheet for full comparison.)



COMPARATIVE SPECS	Qpacity ESS	Typical Competitor
Primary Storage	100% Graphene	Lithium-Ion
Battery Cycle Life	20,000—1M	3-6,000
Round Trip Efficiency	99.1%	85-90%
Useable Voltage/Amps	100%	80-90%
Depth of Discharge (DOD)	100%	85-95%
Temperature Range	-40°C to 70°C	-20°C to 60°C
Charge Current Limitation	NO LIMIT	95% Recommended
Discharge Current Limitation	NO LIMIT	80% Recommended
Non-Flammable / Non-Toxic	YES	NO
Thermal Stability	YES	NO
Energy Density	280-300 Wh/kg	180-250 Wh/kg

¹ G. Bakke, 2017. *The Grid: The Fraying Wires Between Americans and our Energy Future*

² David Tice (Director). 2022. *Grid Down, Power Up*. Paul Revere Films. (Can watched at <https://griddownpowerup.com>)

³ <https://www.torquenews.com/14335/meet-teslas-megafactory-capable-producing-10000-megapacks-each-year>

⁴ <https://www.torquenews.com/14335/astonishing-economics-tesla-megapack#:~:text=Tesla%20has%20about%20a%202,course%20of%20a%20Megapack's%20lifetime.>

⁵ One Terawatt is 1,000 gigawatts, which is 1,000 megawatts, which is 1,000 kilowatts. To have perspective on this, an average U.S. household will use about 30 kWh per day. When speaking of size in terms of utility company needs, they usually speak in terms of megawatts or gigawatts. Terawatts is now part of the energy industry lexicon. For reference, 1 terawatt is equal to 1 million megawatts or 1 billion kilowatts.

⁶ U.S. Dept. of Energy. 2020, Dec. *Energy Storage Grand Challenge: Energy Storage Market Report 2020* (Technical Report: NREL/TP-5400-78461; DOE/GO-102020-5497).

⁷ L. Kolodny. 2022, Sep. 20. *Tesla Megapack Battery Caught Fire at PG&E Substation in California*. CNBC.com. <https://www.cnbc.com/2022/09/20/tesla-megapack-battery-caught-fire-at-pge-substation-in-california.html>

⁸ Batteries News. 2020, May 9. *Korea to Tighten Measures for Energy Storage Systems Safety as Batteries Catch Fire*. BatteriesNews.com. <https://batteriesnews.com/korea-measures-energy-storage-systems-safety-batteries-fire>

⁹ W. Mroziak, et al., 2021. *Environmental impacts, pollution sources and pathways of spent lithium-ion batteries*. Energy & Environmental Science, Issue 12, 2021.