SOLAR AND STORAGE FOR ENERGY AND RESILIENCY

A guide for consideration

Utah Clean Energy

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Cover Photo Source: Salt Lake City Public Safety Building, Utah Adventure Journal, November 2015 <*http://utahadvjournal.com/index.php/is-it-getting-hot-in-here*>.

INTRODUCTION

The growing frequency of extreme weather events and the very real threat of a significant earthquake in Utah drives the need for resilient backup power systems. A self-generation power system comprised of solar photovoltaics coupled with battery storage not only provides robust backup power in the event of an emergency but also helps manage day-to-day energy usage. The versatility and scalability of solar and storage and the ability to combine a solar and storage system with traditional backup generators makes solar and storage an ideal solution for critical facilities that require uninterrupted power supply such as hospitals, communication centers, radio stations, and community emergency shelters.

A 330 kilowatt solar installation at the Natural History Museum of Utah. Utah's solar capacity has grown rapidly in recent years. Retrofitting existing solar installations with battery storage can provide resilient backup power in the event of a grid outage.[1]

The cost to install solar has fallen about 75% since 2006,[2] and solar installations are an increasingly popular way to save money on utility bills. Battery storage costs have undergone similar price declines, falling by more than 50% since 2010, making solar with storage an increasingly viable solution for energy management in addition to emergency power.[3] Future cost declines are expected to make commercial and industrial use of batteries for energy storage a cost-effective choice in certain markets within 3-5 years, amplifying the advantages of solar energy and making solar and storage systems an attractive economic offering in these markets.[4]

As the solar market continues to grow in Utah, planning for storage by building storage-ready projects opens the door for future cost savings. Understanding best practices for solar and storage systems will prepare facilities to incorporate solar and storage into new construction, scheduled renovations, or even retrofits as storage costs continue to fall and technology improves.

As you consider solar for your facility, this guide will help you understand how you can incorporate storage into your project or make your project 'storage-ready' such that storage can be incorporated cost-effectively in the future.

[1] Utah Natural History Museum, <https://newsdesk.nhmu.utah.edu/?q=media/572>.
[2] GTM Research & Solar Energy Industries Association, *U.S. Solar Market Insight 2015 Year-in-Review*, March 2016. <http://www.seia.org/research-resources/solar-industry-data>.
[3] Moody's Investor Service, "Declining battery prices could lead to commercial and industrial customer adoption in 3-5 years," Sept 2015 <https://www.moodys.com/research/Moodys-Declining-battery-prices-could-lead-to-commercial-and-industrial--PR_335274>.
[4] *Ibid.*

CONSIDERATIONS FOR SOLAR AND STORAGE OR STORAGE-READY SYSTEMS

1. **Determine your backup power goals:**

   Solar and storage systems can be used to provide backup power for key critical loads, to provide power to an entire facility, or to provide supplementary power to extend the life of a backup generator. Decisions about battery technologies will be guided by your backup power goals

2. **Isolate critical loads on the same circuit:**

   In order for solar and storage to provide power to critical loads in the event of a grid failure, those critical loads must be isolated on the same circuit. Isolating critical loads during construction or renovation will prepare your facility to add solar and storage at a later date.

3. **When installing solar, choose a battery-ready solar inverter**

   Existing solar installations can be retrofitted with battery storage more easily if they include inverters that have the additional functionalities required to integrate battery storage. For more information, refer to the Technical Options section below.

4. **Identify a location for the batteries which is of sufficient size and well ventilated**

   Batteries must be located onsite and must be directly connected to the solar installation. The size of the batteries will depend on the battery technology and the anticipated power needs of the building. Electrical code requirements for batteries address safety concerns and require batteries to be kept on appropriate racking in a well ventilated location.[5] Anticipate the location of battery storage and make accommodations during construction or renovations to prepare for the addition of storage.

5. **Refer to Clean Energy Group's "Solar+ Storage Project Checklist,"** which is designed to help building owners and developers assess whether solar and storage battery systems make sense for their buildings.[6]

[5] National Fire Protection Association National Electric Code 70, Article 480 Storage Batteries <http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=70>.
[6] Clean Energy Group, "Solar + Storage Project Checklist," <http://www.cleanegroup.org/ceg-resources/resource/solar-storage-project-checklist/>.

TECHNICAL OPTIONS

Solar Panels

Solar panels provide power for a solar and storage system. Solar panels generate direct current (DC) power which must be converted to alternating current (AC) power to provide usable power for a building. Solar panels can be located on rooftops, carports, other structures, or even stand alone in open areas.

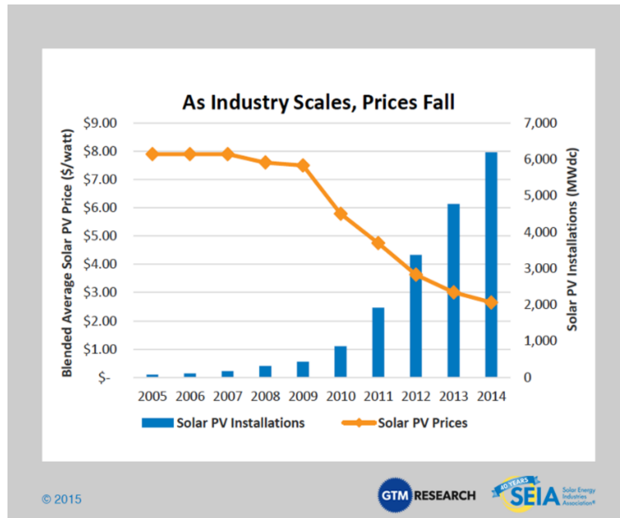

Figure 1: The cost of solar energy has fallen more than 75% since 2006.[7]

Batteries

There are several factors to consider when selecting a battery for a solar and storage system, including cost, energy density, expected lifespan, and safety. All batteries store DC power.

- **Lead acid batteries** are the oldest rechargeable battery technology and are commonly found in automobile engines. Whereas car batteries are designed to remain near full charge, lead acid batteries designed for storage are able to be discharged to 45% - 75% of their rated capacity so that they can withstand repeated charging and discharging. They have a low energy density, thus occupying more space, and have a shorter lifespan than lithium ion batteries.
- **Lithium ion batteries** are commonly used in laptops and electric vehicles. They have a high energy density thus making them lighter and smaller. There are several types of lithium ion batteries currently on the market, each made from a different lithium compound. Lithium ion batteries have a longer lifespan than lead acid batteries because they can be charged and discharged more frequently. Proper installation, maintenance, and use of lithium ion batteries is important to avoid overheating, which can create a fire hazard.

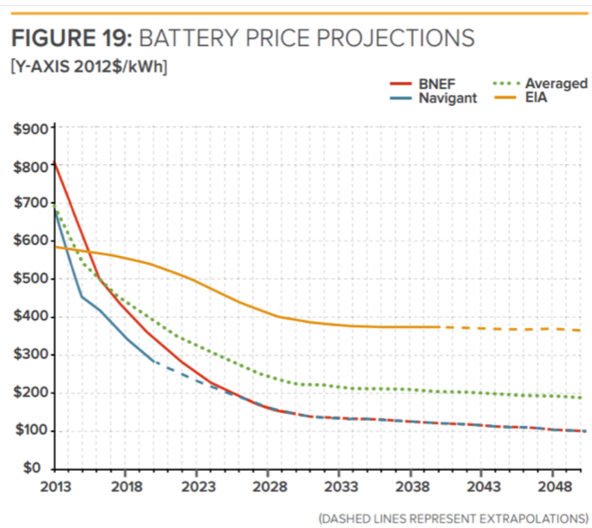

Figure 2: The cost of lithium ion batteries is expected to decline rapidly.[8]

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[7] *Solar Energy Industries Association Q2 2015 Solar Market Insight Fact Sheet*, <http://www.seia.org/research-resources/solar-industry-data>.
[8] *Rocky Mountain Institute, The Economics of Grid Defection*, <http://www.rmi.org/electricity_grid_defection>.

- **Flow Batteries** are a new type of rechargeable battery. Flow batteries consist of two liquid electrolyte compounds which are pumped across a membrane in one direction to produce electricity and in the opposite direction to charge the battery. Flow batteries are very safe because the electrolytes are stored in separate tanks. They can be cycled 10,000 or more times, making them superior to lead acid and li-ion batteries. However, at this time, their relatively high cost, low efficiency and low energy density is still a disadvantage.

Advances in battery technology have brought down the cost and the size of batteries.[9]

Recycling batteries

Some of the batteries used for storage contain toxic metals, and proper recycling is important to prevent pollution and avoid environmental impacts.

- **Lead acid batteries** are recycled more than any other consumer product in the country. Disposal of lead acid batteries into landfills is illegal in most states.[10] During the recycling process, lead can be easily extracted and reused multiple times. Recycling centers must first remove combustible material using a gas-fired thermal oxidizer and must mitigate pollution created by the process of burning using scrubbers.[11]
- **Lithium ion batteries** do not pose as significant an environmental concern but there are benefits to recycling them. Lithium ion batteries are composed of metals that have little or no recycling value such a cobalt, nickel, and manganese, so the economics of recycling these batteries isn't favorable.[12] However, as increasing numbers of lithium ion batteries enter the market, recycling of lithium ion batteries is expected to be one of the main sources of future lithium supply.

Charge Controllers

A battery charge controller regulates the DC power produced by the solar array to prevent overcharging the batteries. If the power input to the battery is not controlled it can result in damage to the batteries and poses a safety hazard.

Inverters

Solar inverters are used to convert DC power produced by solar panels (or the DC power that is stored in batteries) to AC power. A grid-connected solar and storage system must have a specific kind of inverter if it is to provide backup power in the event of a grid failure. A standard solar inverter is designed only for converting DC power to AC power, and it will shut off in the event of a grid failure to protect lineman working on the power lines.

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[9] PV Magazine, "Strong potential growth for storage, distributed generation and microgrids," November 28 2012, <http://www.pv-magazine.com/news/details/beitrag/strong-potential-growth-for-storage--distributed-generation-and-microgrids_100009373/#ixzz44M7zdxJ8>.
[10] Waste Management World, "The Lithium Battery Recycling Challenge," https://waste-management-world.com/a/1-the-lithium-battery-recycling-challenge
[11] Battery University, "How to Recycle Batteries," <http://batteryuniversity.com/learn/article/recycling_batteries>
[12] Waste Management World Op. Cit.

In order for a solar and storage project to function both on and off the grid, the inverter must be able to provide several functions. It must be able to monitor and communicate grid status, convert DC electricity produced by solar panels to AC electricity, provide DC electricity to charge the battery, convert DC electricity stored in the battery to AC electricity for onsite use, and curtail power production from the solar panels as needed to prevent damaging the battery

- **Dual inverters** are used in a DC-coupled solar and storage system and can accomplish all these functions with a single inverter. A DC-coupled battery stores the DC power produced by solar panels without conversion and can also convert the power to AC for use in a building. Some dual inverters, known as **Grid Forming Inverters**, can also regulate voltage and frequency when the solar and storage system is isolated from the grid. When installing a solar project, choosing a Dual Inverter or Grid Forming Inverter for the solar installation will allow for the future addition of storage at a lower cost. See Figure 3, below.
- **Grid-tied inverters** are used for grid-tied solar systems, and cannot provide islanding or backup functionality. Grid-tied inverters can be used to convert DC battery power to AC power for use in homes or buildings as long as they remain grid connected.

- **Stand-alone inverters** are used for off-grid applications. These convert the DC power from the solar panels and battery to AC power for use in homes or buildings that are not connected to the grid.

An existing solar installation that does not have a Dual Inverter must be retrofitted to accommodate storage by either replacing the existing inverter with a Dual Inverter or adding AC-coupled batteries. AC-coupled batteries store power after it has been converted to AC power by a standard solar inverter. A second battery inverter is required to convert the AC power back to DC in order to charge the battery, and to reverse the conversion when the battery power is needed to charge the building.

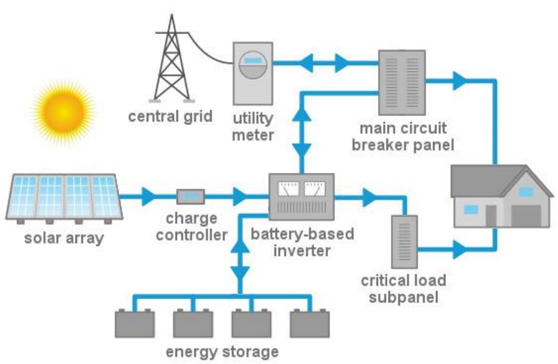

Figure 3: *DC-Coupled Solar and Storage System*
A single battery inverter converts energy to charge batteries and power the building.[13]

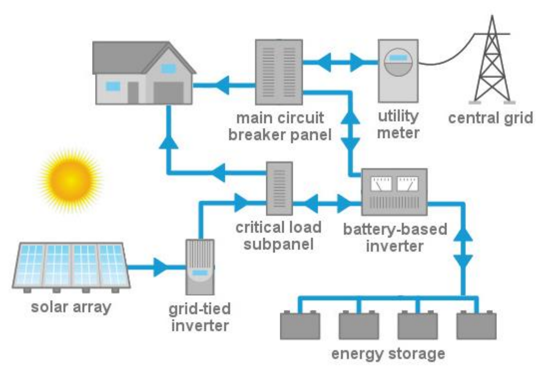

Figure 4: *AC-Coupled Solar and Storage System*
A grid-tied inverter converts DC energy to AC energy. A second battery inverter converts AC power to DC to charge the battery.[13]

[13] *Source: Clean Energy Group, Solar + Storage 101: An Introductory Guide to Resilient Solar Power Systems" <http://www.cleanegroup.org/ceg-resources/resource/solar-storage-101-an-introductory-guide-to-resilient-solar-power-systems/>.*

While this configuration is necessary to retrofit a grid-tied inverter with storage, an AC-coupled system is less efficient than a DC-coupled system. For this reason, it is recommended that all inverter options are evaluated when installing solar. If battery storage capability is desired in the future then a storage-ready Dual Inverter is likely more cost effective in the long term.

SOLAR, STORAGE AND MICROGRIDS

If protecting a facility from grid outages is a priority and an objective, then having a system that can isolate from the grid and operate autonomously is critical. A microgrid is an energy system of interconnected loads that consists of one or more form of distributed generation and may also include energy storage that can function while connected to the grid and can also function during grid outages by providing resiliency benefits/emergency power.[14] Microgrids can be utilized to power critical loads on a single circuit, in a single building, or across an entire campus. A microgrid can act as a single controllable entity and can operate in either grid-connected or islanded mode.[15]

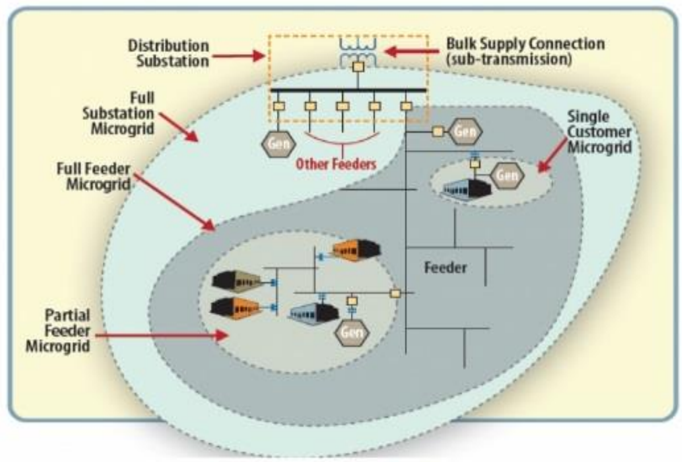

Figure 5: *A microgrid is scalable to serve a single customer or a larger section of the distribution system.[16]*

Solar and storage can be integrated with generators to extend the life of existing backup power sources. In this case, to maintain generator reliability during a grid outage and to control system voltage and frequency, at least one generator must run at all times, at a minimum of 30% of its rated capacity.[17] Additional generators can be ramped up or down in accordance with changes in load and solar energy output.

Additional information about resilient solar hardware components and systems can be found in the NY Solar Smart DG Hub Hardware Factsheet.[18]

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[14] CUNY, NY Solar Smart DG Hub, "Glossary," <http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower/DG_Hub_Glossary.pdf>.
[15] U.S. Department of Energy Office of Electricity Delivery & Energy Reliability <http://energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-system>.
[16] *Ibid.*
[17] CUNY, NY Solar Smart DG Hub, "Hardware Fact Sheet." <http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower/DecHardwareFactSheet.pdf>.
[18] *Ibid.*

IMPLEMENTATION MODELS

Solar energy systems are an increasingly popular choice for electricity customers who want to reduce their monthly utility bill and generate clean energy on site. When paired with battery storage, the benefits of solar are multiplied. Solar and storage systems can provide a variety of services, from resiliency benefits like emergency power to economic benefits like utility bill savings. The design of a solar and storage system will depend on the intended function (or functions) of the system. Solar and storage systems can be broadly grouped into those designed to provide off-grid power and those designed to provide grid-connected power. Grid-connected solar and storage installations can access a wide variety of resiliency and economic benefits.

OFF-GRID
Solar and Storage System

RESILIENCY BENEFITS: Provide standalone power where grid access is unavailable.

GRID-CONNECTED
Solar and Storage System

RESILIENCY BENEFITS: Provide backup power for a grid-connected building.

ECONOMIC BENEFITS: Manage energy consumption to reduce utility bill payments.

	Resiliency	**Energy charge reduction:** Reduce total number of kilowatt-hours used in a month.	**Demand charge reduction:** Demand charges are based on the 15 minute period of peak usage each month.	**Ancillary services:** Some customers are compensated for services which improve grid functionality, including voltage and frequency control. (Not currently available in Utah).
SOLAR BENEFITS:	Provides limited standalone power when the sun is shining if paired with an inverter that features an emergency power outlet.	Solar panels are used to offset energy purchases from the utility while the sun is shining. Excess energy is sent to the grid in exchange for credits which are used to offset future energy purchases.	To the extent that this peak occurs during the day, solar may be able to reduce peak demand (and therefore demand charges), however solar cannot be discharged reliably for this purpose.	Some companies are developing advanced solar "smart inverters" which will be able to perform grid-balancing functions that ease the integration of large amounts of solar.
	+	+	+	+
STORAGE BENEFITS:	Can both produce and store energy in order to provide enough power to supply a specific load with power indefinitely.	Batteries store energy and discharge during times when the cost of purchasing energy from the utility is highest, achieving additional savings on energy costs.	Batteries store energy onsite and discharge energy during times of predicted peak usage to reduce demand charges.	Some utilities allow solar and storage systems to bid into a market to provide ancillary services and receive compensation.

CASE STUDIES

OFF-GRID SOLAR AND STORAGE:

The City of Houston purchased 17 solar powered shipping containers that can be dispatched as needed in the event of an emergency, such as a hurricane, that disrupts the power grid. The containers function as mobile microgrids that can be used to provide emergency power for charging critical devices or keeping medications cool. During non-emergency times, the containers will be used to provide mobile power for the Houston Parks Department or for special events.[19]

GRID-CONNECTED SOLAR AND STORAGE:

Florida's SunSmart Emergency Shelter program equipped more than 100 public schools with solar + storage microgrid systems that can power lighting and electrical outlets at the schools if the grid is disrupted by a storm. Each school can provide emergency shelter for 100 – 500 people. During normal operations, the schools are able to use the solar panels to offset daily electricity usage and save $1,500 - $1,600 annually.[20]

[19] *Source: Houston Public Media, "Houston Gets Emergency Solar-Powered Generation Units," April 18, 2011 <http://www.houstonpublicmedia.org/articles/news/2011/04/18/27049/houston-gets-emergency-solar-powered-generation-units/>.*
Photo: Examiner.com, "Woodrow Wilson Montessori School is into solar-powered energy," September 3 2012, < http://www.examiner.com/article/woodrow-wilson-montessori-school-is-into-solar-powered-energy>.
[20] *Source: Clean Energy Group, "SunSmart Emergency Shelters Program," <http://www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/sunsmart-emergency-shelters-program/>*
Photo: Florida Solar Energy Center <http://www.fsec.ucf.edu/En/education/sunsmart/index.html>.

BARRIERS TO IMPLEMENTATION

Although solar and storage systems offer significant resiliency benefits, barriers remain that limit implementation of solar and storage systems.

1. **Cost of storage:**
   Although the cost of storage has fallen rapidly, solar and storage systems still entail a long payback period in Utah. Projections indicate that the cost of solar and storage installations will continue to fall and solar systems with storage will be cost-competitive with grid power in some locations by 2020.[21] Facility managers who consider best practices for installing solar and storage (or building solar and storage-ready) will be prepared to take advantage of the benefits of solar and storage when the technologies are cost-competitive.

2. **A value for ancillary benefits:**
   Currently, Utah utilities do not offer payment for ancillary services that solar and storage could provide to the utility. Potential ancillary services include demand response and frequency regulation services that reduce could reduce utility costs and create a more responsive and resilient grid. Although Utah customers are not currently compensated for these services, new rate structures could create additional value for solar and storage installations while also reducing utility costs for all customers.

3. **Lack of clarity in Federal Investment Tax Credit**
   The IRS does not explicitly list energy storage as an approved technology that is eligible for the Federal renewable energy tax credit. The IRS has requested feedback regarding the ITC and its applicability to storage and is projected to issue proposed regulations in spring 2017 and issue final regulations in fall 2018.[22]

4. **Low cost of electricity in Utah**
   Without compensation for ancillary services, the economic benefit of battery storage comes from energy and demand charge reductions. The relatively low cost of electricity in Utah creates a long payback period for solar and storage installations in Utah. As the cost of battery technologies continues to fall, the value proposition for solar and storage systems will improve.

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[21] Rocky Mountain Institute, *op. cit.*, P7
[22] Deloitte, "Financing Energy Storage with Tax Credits," September 28, 2015
<http://www2.deloitte.com/us/en/misc/search.html#qr=investment%20tax%20credit>.

APPENDIX A – Battery Types and Specifications

This table is adapted from the CUNY NY Solar Smart DG Hub, Resilient Photovoltaic (PV) Systems Hardware Factsheet, available at http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower/DecHardwareFactSheet.pdf

Specifications	**Battery Types**						
	Lead Acid	***Lithium Ion***					***Flow Batteries***
	Valve Regulated	*Lithium iron phosphate*	*Lithium nickel manganese cobalt oxide*	*Lithium nickel cobalt aluminum oxide*	*Lithium titanate*	*Lithium manganese oxide*	*Redox*
Usage	Resiliency, Grid Support, Peak load shifting, Intermittent energy smoothing, UPS	Resiliency, Grid Support, Peak load shifting, Intermittent energy smoothing, UPS					Resiliency, Grid Support, Peak load shifting, Intermittent energy smoothing, UPS, Bulk power management
Energy Density (Wh/kg)	30-50	90-120	150-220	200-260	70-80	100-150	10-20
Lifetime cycles (80% depth of discharge)	200-300[23]	1000-2000	1000-2000	500	3000-7000	300-700	10000+
Efficiency (%)	80-90%	90-95%					65-85%
Charge Rate	8-16hrs	2-4hrs	2-4hrs	2-4hrs	1-2hrs	1-2hrs	Depends on size of the tank and cell stack
Cost	$150-300/kWh	$400/kWh	$428-750/kWh	$240-380/kWh	$2000/kWh	$250-300/kWh	$680-800/kWh
Thermal Runaway Temp and Stability[24]	Considered thermally safe	270°C Among the safest type of li-ion battery	210°C Less stable than lithium iron phosphate	150°C Least stable	Among the safest type of li-ion battery	250°C Medium stability	Very safe since storage of electrolyte is separate from power generation unit
Advantages	Well-known, reliable technology, can withstand deep discharges, relatively low cost, ease of manufacturing	High energy density, able to withstand deep discharges, and long cycle lives					Well suited for bulk storage, long cycle life, and easy to scale up the amount of energy stored by simply making the tanks larger
Disadvantages	Relatively low number of life cycles and lower energy density	More expensive than lead acid systems and may become thermally unstable. Overheating or short circuits in Li-ion cells may cause thermal run-away—a phenomenon where the internal heat generation in a battery increases faster than it can dissipate. This heat can damage or destroy the cells and is a potential source for fires. Electronic protection circuits are added to the battery pack to prevent thermal run-away					Relatively high cost, low efficiency and low energy density; high maintenance with pumps that often leak and precipitate out

[23] Managing the depth of discharge for lead acid batteries increases the lifespan of these batteries

[24] Battery University, "Types of Lithium Ion," <http://batteryuniversity.com/learn/article/types_of_lithium_ion>, accessed on 15 March 2016. *Note that the battery technology is rapidly changing with their growth in the market.*

ADDITIONAL RESOURCES

1. Clean Energy Group. *Solar+Storage Project Checklist*. January 2016. http://www.cleanegroup.org/wp-content/uploads/Solar-Storage-Checklist.pdf

2. Clean Energy Group. *Solar+Storage 101: An Introductory Guide to Resilient Power Systems*. March 2015. http://www.cleanegroup.org/wp-content/uploads/Energy-Storage-101.pdf

3. The City University of New York, Smart Distributed Generation Hub – Resilient Solar Project. *Hardware Factsheet*. October 2015. http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower/DecHardwareFactSheet.pdf

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5. Houston Public Media, *Houston gets Emergency Solar-powered Generation Units.* April 2011. http://www.houstonpublicmedia.org/articles/news/2011/04/18/27049/houston-gets-emergency-solar-powered-generation-units/

6. Clean Energy Group, *SunSmart Emergency Shelters Program*. http://www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/sunsmart-emergency-shelters-program/

7. Clean Energy Group, *Stafford Hills Solar Farm and Microgrid.* http://www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/stafford-hill/

8. Green Mountain Power, *Green Mountain Power to Offer Tesla Home Battery.* May 2015. http://news.greenmountainpower.com/manual-releases/Green-Mountain-Power-to-Offer-Tesla-Home-Battery?feed=d51ec270-a483-4f6c-a55e-8e5fbe2238c2

About Utah Clean Energy: Utah Clean Energy is a non-profit, non-partisan public interest organization partnering to build the clean energy economy. We are committed to creating a future that ensures healthy, thriving communities for all, empowered and sustained by clean energy.

About the SunShot Initiative: The U.S. Department of Energy SunShot Initiative is a collaborative national effort that aggressively drives innovation to make solar energy fully cost-competitive with traditional energy sources before the end of the decade. Through SunShot, the Energy Department supports efforts by private companies, universities, and national laboratories to drive down the cost of solar electricity to $0.06 per kilowatt-hour. Learn more at energy.gov/sunshot

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