SOLAR AND STORAGE FOR ENERGY AND RESILIENCY

A guide for consideration

Utah Clean Energy

With support from:
U.S. Department of Energy SunShot Initiative

UTAH CLEAN ENERGY

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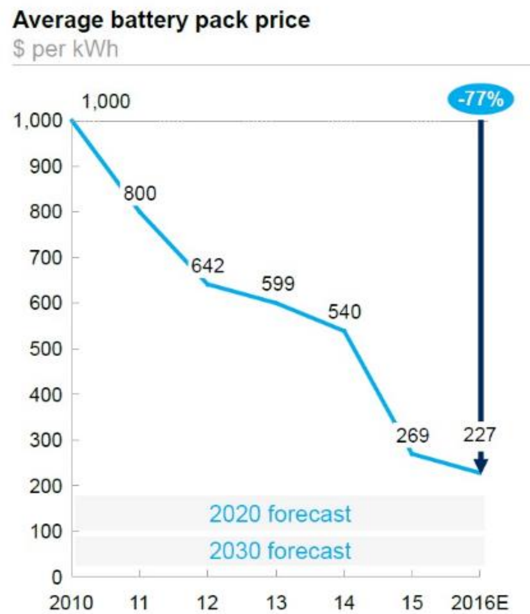
INTRODUCTION

The growing frequency of extreme weather events and the threat of a significant earthquake in Utah drives the need for resilient backup power. Solar panels paired with battery storage not only provide robust backup power in the event of an emergency but also help manage day-to-day energy usage and costs. Solar and storage systems are versatile, scalable, and can be paired with a traditional backup generator to provide backup power for critical facilities that require uninterrupted power supply such as hospitals, communication centers, and community emergency shelters.



The cost of battery storage fell roughly 80% between 2010 and 2016, from ~$1,000/kWh to ~227/kWh, and battery costs continue to trend downwards.
Source: McKinsey & Company, "Electrifying insights: How automakers can drive electrified vehicle sales and profitability."[2]

The cost to install solar has fallen about 75% since 2006[1], and solar installations are an increasingly popular way to save money on utility bills. Battery storage costs have fallen by nearly 80% since 2010, making solar with storage an increasingly economic solution for energy management in addition to emergency power.[2]

Utah's solar market continues to grow, and 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.

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] 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>.
[2] McKinsey & Company, "Electrifying insights: How automakers can drive electrified vehicle sales and profitability," January 2017 <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electrifying-insights-how-automakers-can-drive-electrified-vehicle-sales-and-profitability>.

CONSIDERATIONS FOR SOLAR AND STORAGE (OR STORAGE-READY) SYSTEMS

1. **Gather data about your energy usage:**

In order to optimize your solar and storage system, you will need to understand your building's energy usage in detail – ideally on an hourly basis, for commercial customers, or a 15-minute basis, for some residential solar customers.[3] Rocky Mountain Power does not provide detailed load data for customers, so if your building's electricity usage is not already monitored on an hourly basis, identify energy service companies or monitoring equipment that can gather hourly consumption data for 12 months. If hourly load data is not available, gather hourly load data from time periods where energy use deviates from the norm (for example, summer months when peak load is high) and extrapolate for other times of the year, or look for proxy data from a facility with similar operating characteristics.

[3] Commercial customers are typically subject to demand charges or peak or time-of-use energy charges, in which case it is important to have hourly load data. Residential customer rates do not vary hourly, however residential customers who install solar through the Transition Program (after November 14, 2017) will see their generation and consumption netted on a 15 minute basis. For this reason, 15-minute load data is preferable to evaluate the economics of battery storage.

2. **Evaluate and isolate critical loads:**

   In order to evaluate the emergency benefits of solar and storage it is important to have data about the energy usage of critical loads. Consult with your facility manager to identify critical functions (including energy and demand needs for each function). Ideally, critical loads should also 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. **Determine your backup power goals:**

   Solar and storage systems can 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. Once you have gathered data about your energy usage and critical loads, you can estimate sizing for a solar and storage system to power your facility using tools like the SolarResilient calculator[4].

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.

5. **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.

6. **Refer to Clean Energy Group's "Solar+ Storage Project Checklist."**

   This checklist is designed to help building owners and developers solar and storage battery systems.[6]

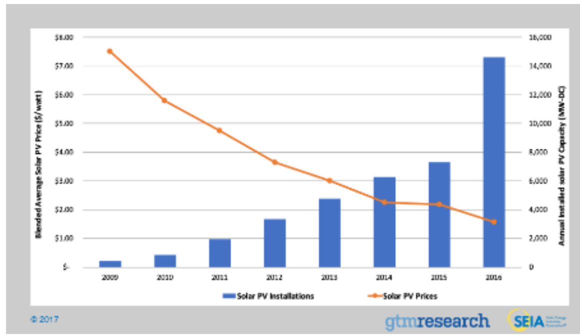
[4] SolarResilient <https://solarresilient.org/>.
[5] National Fire Protection Association National Electric Code 70, Article 480 Storage Batteries <http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=70>.
[6] Clean Energy Group, "Solar + Storage Project Checklist," <http://www.cleanegroup.org/ceg-resources/resource/solar-storage-pr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

Cost of Solar
$/watt

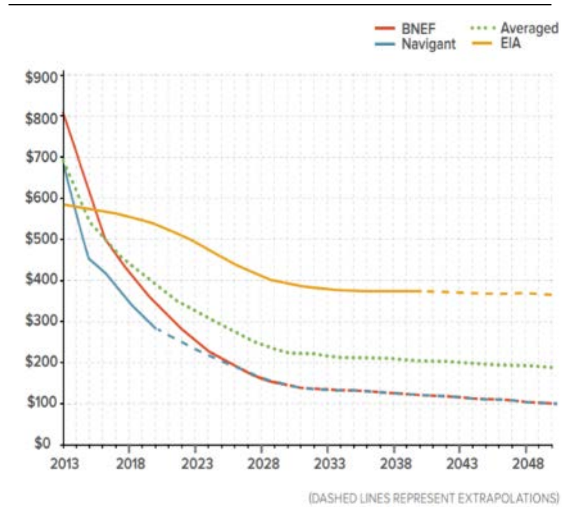


The cost of solar energy has fallen more than 75% since 2006.
Source: Solar Energy Industries Association, *https://www.seia.org/solar-industry-data*

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.

Cost of Battery Storage
$/kWh



The cost of lithium ion batteries is expected to decline rapidly.
Source: Rocky Mountain Institute, The Economics of Grid Defection, http://www.rmi.org/electricity_grid_defection

- **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 designed to withstand repeated charging and discharging, but they are larger in size and have a shorter lifespan compared to lithium ion batteries.
- **Lithium ion batteries** are commonly used in laptops and electric vehicles and are lighter and smaller than lead acid batteries. There are several types of lithium ion battery compounds currently on the market. Lithium ion batteries have a longer lifespan than lead acid batteries and 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.

- **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, however they are currently more expensive than lithium ion and lead acid alternatives.

Recycling batteries

Batteries contain toxic metals, so 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.[7] 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.[8]

- **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.[9] 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.

[7] Waste Management World, "The Lithium Battery Recycling Challenge," https://waste-management-world.com/a/1-the-lithium-battery-recycling-challenge
[8] Battery University, "How to Recycle Batteries," <http://batteryuniversity.com/learn/article/recycling_batteries>
[9] Waste Management World Op. Cit.

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.

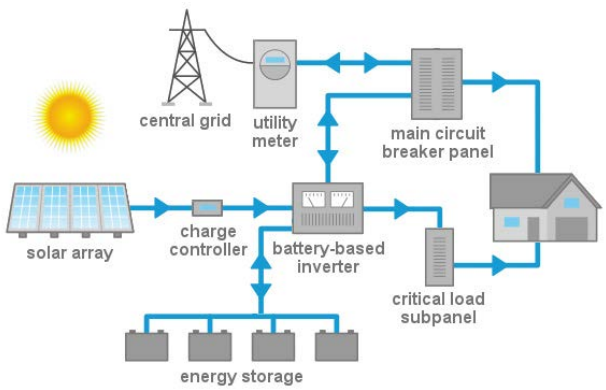
Inverters

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.

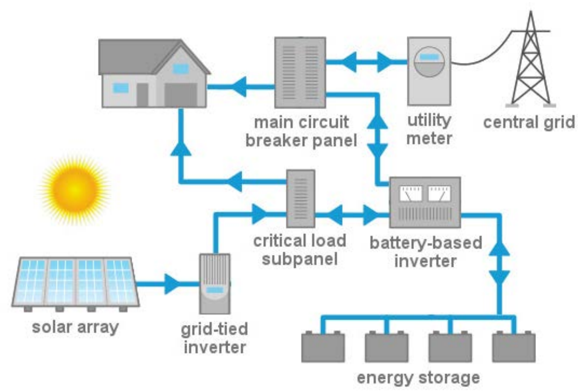
In order for a solar and storage project to function both on and off the grid, the inverter must be able to provide several functions. It must be able to monitor and communicate grid status, convert DC electricity produced by solar panels to AC electricity, provide DC electricity to charge the battery, 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.



DC-Coupled Solar and Storage System:
A single battery inverter converts energy to charge batteries and power the building.

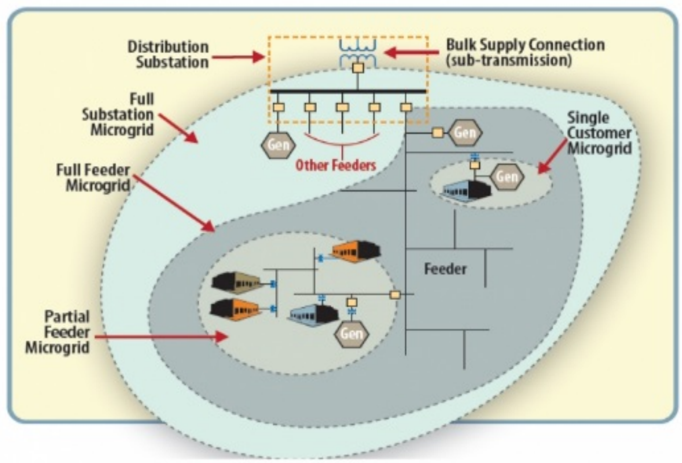


AC-Coupled Solar and Storage System:
A grid-tied inverter converts DC energy to AC energy. A second battery inverter converts AC power to DC to charge the battery.

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



A microgrid is scalable to serve a single customer or a larger section of the distribution system
Source: U.S. Department of Energy Office of Electricity Delivery & Energy Reliability

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.[10] 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.[11]

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.[12] 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.[13]

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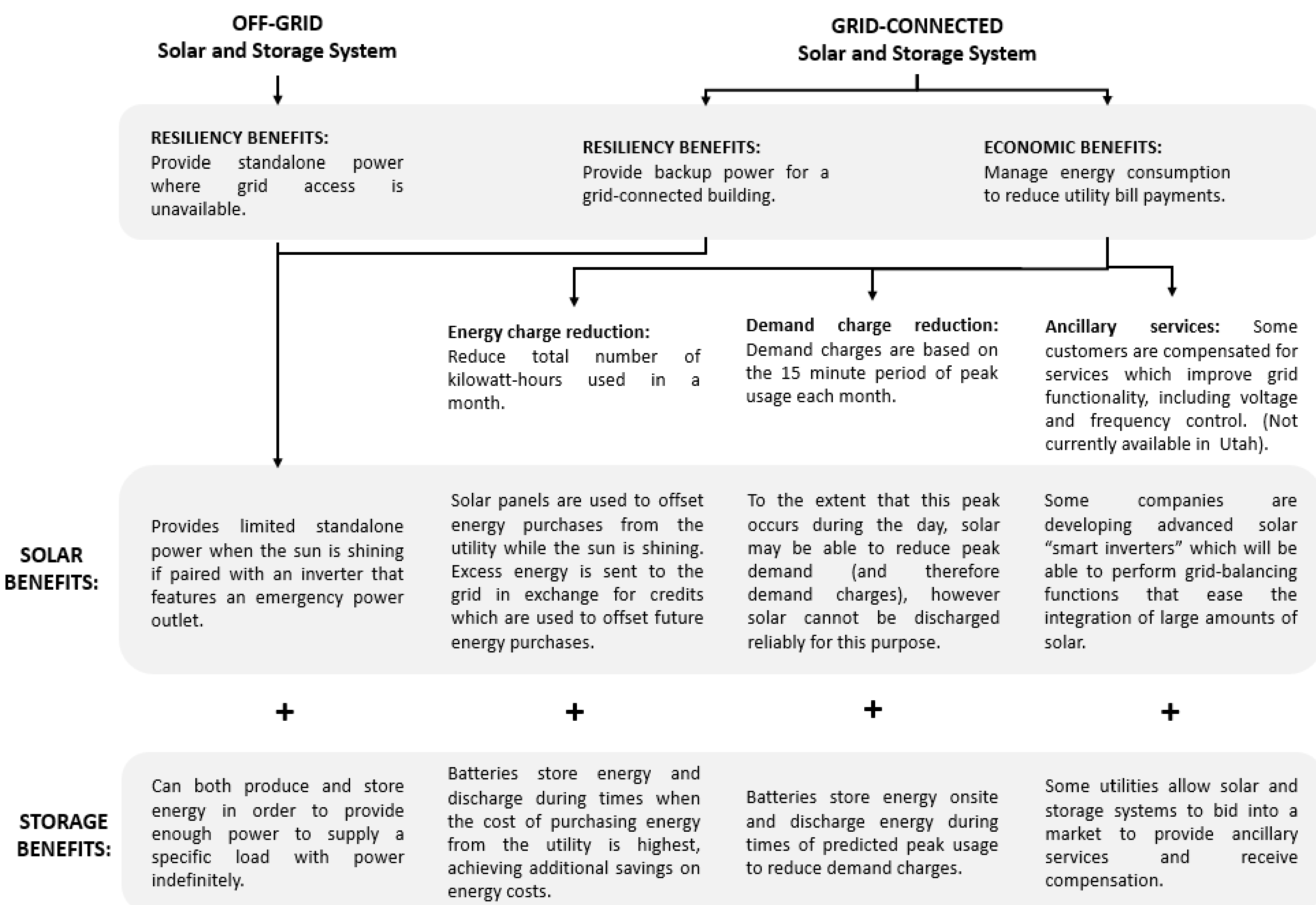
[10] CUNY, NY Solar Smart DG Hub, "Glossary," <http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower/DG_Hub_Glossary.pdf>
[11] U.S. Department of Energy Office of Electricity Delivery & Energy Reliability http://energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-system
[12] CUNY, NY Solar Smart DG Hub, "Hardware Fact Sheet." <http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower/DecHardwareFactSheet.pdf>
[13] *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.



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.

Photo: Mobile Grid http://www.mobilegrid.com/project-photos/.

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.

Photo: U.S. Department of Energy, Office of Energy Efficiency &Renewable Energy https://energy.gov/eere/articles/floridas-sunsmart-program-helps-provide-power-schools-when-storms-strike.

GRID-CONNETED SOLAR AND STORAGE: The Hartley Nature Center in Duluth, Minnesota retrofitted an existing solar array with battery storage to improve resilience and economic security. During the summer of 2017, a power outage forced the center to cancel a week of youth camps, resulting in $14,000 of lost revenue. If the grid goes down, the battery storage can power basic business operations, allow the building to serve as a community shelter, or even serve as a base of operations for the city's emergency response efforts.

Photo: Clean Energy Group https://www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/hartley-nature-center/.

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.[14] 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. **Difficulty accessing load data:**

   Rocky Mountain Power does not provide detailed load data for customers, so it is impossible to know how much energy a building uses at different times of day without installing a third-party monitoring system. This data is necessary to determine the appropriate size for a battery storage system or estimate economic savings from the batter storage. Customers can install a third-party monitoring system to gather load data, however this adds time and cost to the process of completing solar and storage evaluation.

3. **A value for benefits:**
   Currently, Utah utilities do not recognize ancillary services and other benefits that solar and storage could provide to the utility. Potential benefits include discharging power during times of peak demand (or charging during times of low demand), and ancillary services include demand response and frequency regulation services that 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.

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. Utah does not currenly offer a tax credit for investments in battery storage, but such a credit would improve the economics and encourage battery storage adoption.

[14] Rocky Mountain Institute, *op. cit.*, P7

ADDITIONAL RESOURCES

Tools & Checklists

1. **Solar & Storage sizing calculator** | San Francisco Department of the Environment
   This tool allows any building owner to estimate equipment sizing for a solar and storage system to provide backup power during a grid outage. https://solarresilient.org/

2. **Solar+Storage 101: An Introductory Guide to Resilient Power Systems** | Clean Energy Group
   This guide provides a basic technical background and understanding of solar+storage systems, including the basic layout and components. http://www.cleanegroup.org/wp-content/uploads/Energy-Storage-101.pdf

3. **Solar+Storage Project Checklist** | Clean Energy Group
   This checklist serves as a starting point to become familiar with solar+storage technologies, how they work, and what's involved in getting a new project off the ground.
   http://www.cleanegroup.org/wp-content/uploads/Solar-Storage-Checklist.pdf

4. **Resilient Solar PV Factsheet** | The City University of New York
   This fact sheet outlines the resilient PV system designs and components including a detailed battery comparison table listing usage types, lifetime, costs, safety, and other battery characteristics.
   https://nysolarmap.com/media/1451/dechardwarefactsheet.pdf

5. **Economics and Finance of Solar+Storage** | The City University of New York
   This guide is designed to provide solar installers and the general public with an understanding of the economics of solar photovoltaic projects that include battery storage systems (solar+storage) in New York City.
   http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower/DecFinanceFactSheet.pdf

Case Studies

6. **Solar Powered Adaptive Containers for Everyone** | Houston, Texas
   Seventeen mobile solar-powered units power small appliances and devices during emergency situations or widespread power outages. Under normal circumstances, the units are designed to be used for offices, storage, and first aid stations.
   http://www.houstonpublicmedia.org/articles/news/2011/04/18/27049/houston-gets-emergency-solar-powered-generation-units/

7. **SunSmart Emergency Shelters Program** | Florida
   Florida's SunSmart E-Shelter Program has equipped more than 100 public schools with small PV systems and batteries sufficient to keep lights and electrical outlets operating during a grid-outage and enabling these schools to provide emergency shelter for 100-500 people per site. https://energy.gov/eere/articles/floridas-sunsmart-program-helps-provide-power-schools-when-storms-strike

8. **Emergency backup power at Hartley Nature Center** | Duluth, MN

   The Hartley Nature Center retrofitted an existing solar array with battery storage to improve resilience and economic security. The battery storage can power basic business operations, allow the building to serve as a community shelter, or even serve as a base of operations for the city's emergency response efforts. https://www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/hartley-nature-center/

9. **Stafford Hill Solar Farm and Microgrid** | Rutland, VT

   Green Mountain Power built the Stafford Hill Solar Farm to improve resilience following hurricane Irene in 2011. Solar panels, battery storage, a microgrid can provide backup power to a public emergency shelter at the Rutland City High School. In its first year of operation, the project shaved enough peak demand to save its customers approximately $200,000 during a single hour. http://www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/stafford-hill/

10. **Green Mountain Power & Tesla Home Battery** | Vermont

    Green Mountain Power plans to deploy 2,000 Tesla batteries at their customer's homes for a fee of $15 a month or a one-time fee of $1,500. Customers who choose to participate will benefit from backup power when the grid is down, and the program is estimated to reduce the utility's peak load by up to 10 megawatts (the equivalent of taking an average of 7,500 homes off the grid.) https://www.greenmountainpower.com/press/gmp-launches-new-comprehensive-energy-home-solution-tesla-lower-costs-customers/

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 Solar Energy Technology Office 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 https://energy.gov/eere/solar/sunshot-initiative

For questions about this document contact:

solar@utahcleanenergy.org | www.utahcleanenergy.org | www.solarsimplified.org