CSVP Resource Links for Solar Plus Storage

Summary

The Community Solar Value Project (CSVP) has developed this guide to **Resource Links for Solar Plus Storage** as part of its complete Community Solar Solutions toolbox. Whether you're interested in leveraging the integration value of energy storage to enhance your community solar offer, or interested in storage as a way to complement any growing distributed solar portfolio, these resources will support you.

The resource links provided here serve a practical, program-oriented perspective. For example, utility-side, large-scale batteries could be part of a community solar-plus plan, but large-scale batteries are still costly unless market-development incentives are in play. More often, it is easier to access customer-side options, such as controlled thermal storage systems (primarily water heating and ice) and strategic, small-scale batteries, as well as electric vehicles. Therefore, the latter subset of technologies are more prominently featured in this guide. Further, CSVP has focused on system-wide or circuit-level strategies, rather than on mico-grids or resilience-oriented projects. Readers interested in the latter set of strategies will find pointers to useful resources here, but they are not our focus.

All links provided here were accessed in May 2017. If you cannot access a resource due to an expired link, please contact CSVP. In a few cases, resources are archived in the Library of the CSVP website, in order to assure longer-term availability. A directory of what you will find includes:

- Portal Websites and Guidance Documents
- Resources Setting the DER Industry Context for Solar-Plus
- Field Notes on Solar-Plus in the Market
- Utility Planning for Solar-Plus

Portal Websites and Guidance Documents

Community Solar Value Project: http://www.communitysolarvalueproject/

The CSVP is led by Extensible Energy, with Cliburn and Associates, Navigant, and Olivine consultants, and sponsored by the U.S. Department of Energy SunShot Initiative. CSVP aims to increase the net value of community solar, by promoting best practices for strategic design, target market segmentation, procurement and pricing, and solar plus demand response and storage strategies. CSVP is geared primarily for utilities. The website includes a program-design Solutions toolbox, a library, an archive of webinars, citation-rich blogs and more. CSVP has innovated community solar-plus, to bring added grid-integration and marketing value to the customer solar offer. Examples of relevant resources:

Powers, J. and Huffaker, E. (April 2016). *Integrating Demand Response Into Community Solar Programs.* Community Solar Value Project.

This guide presents a scoring method to quantify and classify the attributes of particular demand response (DR) options, including an introduction to controlled thermal storage. It discusses the effectiveness of using DR companion measures with community solar and includes six case studies.

Powers, J. and Barone, R. (May 2017). *Best Steps You Can Take Toward Solar Plus.* Community Solar Value Project webinar.

Clean Energy Group, http://www.cleanegroup.org/

Clean Energy Group (CEG) is a national, nonprofit advocacy organization working on policy, technology and finance programs in the areas of clean energy and climate change. CEG has several projects related to energy storage, including the resilient power project, solar plus storage optimization, and the Energy Storage Technology Advancement Partnership (ESTAP). ESTAP is managed by the Clean Energy States Alliance (CESA), a project of CEG. The CEG website offers a resource library, webinars, news and a listserv. Publications cover solar plus storage for low and moderate income communities, as well as procurement guidance for municipalities. Other examples of relevant resources:

CEG. (2016). *Solar+Storage Project Checklist*. http://www.cleanegroup.org/ceg-resources/resource/solar-storage-project-checklist/

A starting point for developers and planners of solar plus storage community facilities, this checklist guides early-stage planning, understanding policies and standards, addressing critical load management, considerations for solar generation, technologies for energy storage, and financial options.

Mullendore, S. and Milford, L. (2015). *Solar+Storage 101: An Introductory Guide to Resilient Power Systems.* Clean Energy Group. http://www.cleanegroup.org/wp-content/uploads/Energy-Storage-101.pdf

Peak Load Management Alliance, www.peakload.org

The PLMA is a utility-focused organization, which includes interest groups focused on understanding grid-integration issues and solutions. They consider market-ready technologies, including grid interactive water heaters, thermal/ice storage, electric vehicles (EVs) and customer-side battery systems. The CSVP has engaged with PLMA on developing "solar-plus" companion measures. The PLMA website provides information to the public, with extensive support to members. Public resources include:

Hiedik, R. et al. (2016). *The Hidden Battery: Opportunities in Electric Water Heating.* The Brattle Group. http://www.brattle.com/system/news/pdfs/000/001/007/original/The_Hidden_Battery_-_Opportunities_in_Electric_Water_Heating.pdf?1455129462

More than 40% of U.S. households have electric resistance water heating, accounting for 9% of household electricity consumption. This study explores the economic and environmental impacts for utilities and DR aggregators of control strategies and market-ready innovations. Different combinations of systems and scenarios are assessed, supporting the conclusion that grid-interactive water heaters can deliver powerful storage benefits, for both the utility and the customer.

Industry Context for Solar-Plus

While the rapid development of storage solutions to-date is historic fact, there remain many interpretations of market and policy trends. The following resource links provide a foundational overview of storage technology choices and applications and explore different market development pathways.

Burger, S. and Luke, M. (2016). *Business Models for Distributed Energy Resources: A Review and Empirical Analysis*. MIT Energy Initiative. https://energy.mit.edu/wp-content/uploads/2016/04/MITEI-WP-2016-02.pdf

A review of business models for DERs that incorporate DR, energy management systems, electric thermal storage, and solar photovoltaic systems. This report classifies revenue streams, customer segments, and services. It also identifies barriers to faster market growth.

Howland, E. (April 19, 2017). States eye wide-ranging energy storage bills. *Public Power Daily*. http://www.publicpower.org/Media/daily/ArticleDetail.cfm?ItemNumber=47929

This article summarizes current policy initiatives. For example, the Federal Energy Regulatory Commission (FERC) is taking actions, including proposing requirements to "make it easier for energy storage and aggregated distributed resources to participate in wholesale power markets." In Maryland, a recent bill provides a 30 percent tax credit for residential and commercial energy storage investments. Other state developments include those in Nevada, Vermont, California, and Hawaii.

Lazard. (2016). *Lazard's Levelized Cost of Storage — Version 2.0*. Lazard. https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf

An analysis of the levelized cost of storage, assuming a single capital structure and cost of capital, and various other assumptions, based on surveys of industry participants. Grid-scale and behind-the-meter use cases are considered. However, combinations of integrated technologies are not considered.

Maghani, R. and Mulherkar, A. (2016). *Smart Solar: Integration of Storage and Energy Management*. GTM Research (Green Tech Media). http://www.ees-northamerica.com/en/news-press/download-resources/white-paper.html

This white paper, prepared for the EES North America conference in 2016, reviews the literature and introduces concepts related to solar plus storage, particularly for residential projects. It also reviews current participants and business models, presents case studies and discusses the economic outlook. The authors expect the US solar plus storage market to be $6B and 1.2 GW in 2021, or 70 times bigger than in 2015, with 900 MW of behind the meter storage and 300 MW of utility-scale storage.

Maloney, P. (2017). Is Grid Defection Still a Threat to the Utility Business Model? *Utility Dive*. http://www.utilitydive.com/news/is-grid-defection-still-a-threat-to-the-utility-business-model/440272/

This article contrasts three papers on grid defection: a study from Rocky Mountain Institute (Bronski et al., 2015), a study of 1020 residential locations (Hittinger and Siddiqui, 2017) and a study of 99 homes in Texas, California, and Hawaii (Fares and Webber, 2017). It cites RMI, responding to Hittinger and Siddiqui, including the need to consider the cost of maintaining the grid and that grid defection is an important trend, even if it is not yet economic. The article also discusses Alectra utilities in Ontario, a company that is exploring residential solar plus storage.

Perez, R. (2016). Achieving Very High PV Penetration – The Need for an Effective Electricity Remuneration Framework and a Central Role for Grid Operators. *Energy Policy* 96:27-35. http://www.sciencedirect.com/science/article/pii/S0301421516302452

This paper argues that photovoltaic generation can be firmed through storage, curtailment, dispersion, and load shaping. It proposes a value-based remuneration system, considering value of solar and load shaping tariffs, and affecting consumption patterns to match supply/demand, to support these solutions. It provides a useful context for mapping solar plus storage out in future years.

Field Notes on Solar-Plus in the Market

To understand solar-plus technologies and strategies available today, it is helpful to review reports and case studies from the field. Here is a small collection of case studies and news reports that suggest the usefulness of various storage strategies, in a context that is similar to or could lead to a community solar-plus program. See also, case studies via the Portal websites above. In particular, CSVP reports and presentations include field notes on solar-plus in a community solar program context.

Alectra Utilities. (2017). *Power.House Feasibility Study*. Powerstream. https://www.powerstream.ca/attachments/POWER_HOUSE_Feasibility_Study.pdf

This paper reports on a pilot program of 20 residential solar-plus-storage systems. Benefits to customers included power backup and bill savings. It examines a variety of outcomes and market projections.

Axiom Exergy. (2017). Axiom Exergy Energy Storage Assists Whole Foods Market Store in Shifting up to 1040 kWh of Electricity to Lower Costs. *Axiom Exergy*. http://www.axiomexergy.com/news/axiom-exergy-energy-storage-assists-whole-foods-market-store-in-shifting-up-to-1040-kwh-of-electrici

Axiom makes thermal storage systems for grocery stores and cold storage facilities. This system was installed without modification of existing refrigeration equipment or control reprogramming and thermal storage tanks were placed in the loading dock area.

Ciampoli, P. (January 6, 2017). Hawaiian Utilities Map Out Plans for Dramatic Expansion of Renewables. *Public Power Daily*. http://www.publicpower.org/Media/daily/ArticleDetail.cfm?ItemNumber=47317

Article report on Hawaiian Electric Companies plan to provide all of the state's electric power from renewables by 2045. It expects to reach a statewide RPS of 48% by 2020, exceeding a 30% mandate, and to reach 100% renewables by 2040.

Ciampoli, P. (February 23, 2017). Colorado Utility to Pair Battery Technology, Solar in Pilot Project. *Public Power Daily*. http://www.publicpower.org/Media/daily/ArticleDetail.cfm?ItemNumber=47598

This article reports that Xcel Energy will test six residential behind-the-meter battery units, paired with rooftop solar PV systems, as well as six utility-scale battery units on feeder systems, in a neighborhood in Denver. Xcel is partnering with Sunverge Energy and Northern Reliability to install the systems.

conEdison. (2017). *REV Demonstration Project Outline: Commercial Battery Storage.* New York State Department of Public Service. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B8B24C029-D9E5-4561-9630-88A208F6A880%7D

This project, currently in process, partners conEdison with SunPower and SunVerge to create a 1.8 MW/4 MWh virtual power plant, through control of hundreds of residential solar-plus-storage installations. In 2017, conEdison proposed installing 4.2 MW/4.4 MWh of storage by leasing space on customer premises. It will be used to manage peak load and to sell into the wholesale market. ConEdison also proposed deploying a mobile 1 MW/4 MWh storage system

See also, a news summary: **Ciampoli, P. (March 1, 2017). NY Utility Partners with NRG Energy for Latest Storage Project. *Public Power Daily.*** http://www.publicpower.org/Media/daily/ArticleDetail.cfm?ItemNumber=47633

DiOrio, N. et al. (2015). *Economic Analysis Case Studies of Battery Energy Storage with SAM.* National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/64987.pdf

Case studies of the financial benefit of behind-the-meter solar-plus-storage installed by customers in California and Tennessee. This study also explores different dispatch strategies to increase value and reduce demand charges, while considering tariffs and load and generation data to analyze financial benefits. The author identifies conditions that could lead to cost-effectiveness at current battery costs.

Hoff, T., (July 14, 2016). *Two Years Operating a Solar-Plus Home: Does It Work?* Clean Power Research. https://www.cleanpower.com/2016/two-years-solar-home-data/

This blog culminates a series that describes how each step in a solar plus efficiency, load management, EVs and home-battery retrofit impacts home energy use, economics, and carbon impacts. While the study focuses on the home, the principles of solar-plus strategies could extend to community solar as well.

Spector, J. (2016). *Ice Energy Will Launch Residential Ice Storage in First Quarter 2017.* Green Tech Media. https://www.greentechmedia.com/articles/read/ice-energy-will-launch-residential-thermal-storage-in-first-quarter-2017

This article summarizes introduction of a residential 2.5 ton air-conditioning and ice storage system. The storage would cool a house for a least three hours. Base price is comparable to a high-efficiency air conditioner, but with California incentives, the price is comparable to conventional AC. Ice Energy is targeting customers with high time-of-use rates who can benefit from storage during off-peak times.

Spector, J. (2017). *Stem Pilot Marks a Step Forward for Commercial Energy Storage in Hawaii.* Green Tech Media. https://www.greentechmedia.com/articles/read/stem-tests-model-for-networked-commercial-energy-storage-in-hawaii-solar

This article describes a Stem pilot project to deploy a network of 29 grid-assist battery systems at commercial sites in Hawaii, which could provide 1 MW of capacity.

St. John, J. (2016). *NEC Rolls Out Its Low-Cost Behind-the-Meter Battery System.* Green Tech Media. https://www.greentechmedia.com/articles/read/nec-rolls-out-its-low-cost-behind-the-meter-battery-system

This article summarizes how NEC Energy Solutions makes a customer-side system that integrates LG Chem batteries, inverters, and control systems, called the Distributed Storage Solution (DSS). These modular systems scale from 30 to 650 kW and 85 to 510 kWh, for a target retail price of $750/kWh. The system is aimed at reducing balance-of-system and installation costs.

Steffes, P. (2017). *Grid-Interactive Energy Storage.* Archived on CSVP, http://www.communitysolarvalueproject.com/library

This white paper surveys opportunities for grid interactive water heaters. Drawing on experience in the upper Midwest, it shows variability of wind and solar, and how water heaters can respond to an ISO frequency regulation signal. It shows results for a single water heater and 150 grouped water heaters, as well as real-time control of 2.2 MW/5 MWh and 5.4 MW/42 MWh community storage systems.

Vector. (2016). Vector: NZ Leads in Global Power Revolution. *New Zealand Herald.* http://www.nzherald.co.nz/vector/news/article.cfm?c_id=1503810&objectid=11736123

Vector, a utility in New Zealand, has explored innovative programs for DERs. In 2015, Vector offered free solar-plus-storage to participating residential customers. In 2016, the utility installed grid-scale battery storage to upgrade their distribution system, instead of conventional upgrades. The batteries can also be used for backup power during outages. Vector is installing EV charging systems and has a new peer-to-peer energy trading platform, through which customers can sell surplus power directly to other customers. Vector has also recently expanded to offer storage systems in Australia. See also, articles on RenewEconomy.com: http://reneweconomy.com.au/vector-offers-free-solar-tesla-storage-systems-to-nz-consumers-20628/ and http://reneweconomy.com.au/nzs-vector-makes-major-push-australia-battery-storage-market-77231/

Walton, R. (2015b). Tesla Battery Storage Tapped for Texas' First Community Solar Project. *Utility Dive.* http://www.utilitydive.com/news/tesla-battery-storage-tapped-for-texas-first-community-solar-project/405690/

Utility Planning for Solar-Plus

The following documents offer guidance for utilities that are exploring solar plus battery strategies. Some links address broad questions around renewables integration: What strategies should the utility focus on first? What are the merits of adding storage on the utility side of the meter—or on the customer side? Some of these resources share utility experiences. Others envision how solar-plus strategies would be adapted for different, emerging utility-industry market structures.

Agüero, J.R. et al. (2016). The Utility and Grid of the Future: Challenges, Needs, and Trends. *IEEE Power and Energy Magazine* 14:5. https://doi.org/10.1109/MPE.2016.2577899

This article proposes a framework for utilities to adapt to the changing energy landscape. The framework has four layers: foundational, enabling, application, and innovation. Actions associated with each layer are described.

Fares, R.L. and Webber, M.E. (2017). The Impacts of Storing Solar Energy in the Home to Reduce Reliance on the Utility. *Nature Energy* 2:17001. doi:10.1038/nenergy.2017.1

This article summarizes trade-offs in energy use and emissions for residential households of storing on-site solar energy in batteries. The authors found that a battery could reduce peak power demand by 8-32% and peak power injection by 5-42%. Inefficiencies in storage, however, increase annual energy consumption by 324-591 kW. See also, Maloney, in *Industry Context* section, above .

Fortune, J. et al. (2014). *CPUC Energy Storage Use Case Analysis*. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=3143

This report presents models, called use cases, for customer-sited storage that share benefits between load serving entities (e.g.. utilities) and customers. Storage systems could be used to manage customer bills and/or to manage the distribution grid. It also considers cooperative or third-party asset ownership for behind-the-meter, utility-controlled storage. Several storage technologies are considered.

Green, J. and Newman, P. (2017). Citizen Utilities: The Emerging Power Paradigm. *Energy Policy* 105:283-93. doi.org/10.1016/j.enpol.2017.02.004

The transformation of power generation in Perth, Australia, through rapid increase in rooftop solar, may help utilities anticipate and adapt to similar transformations in the U.S. More than 23% of households in Perth have rooftop solar, with 550 MW capacity. The authors anticipate grid parity for solar-plus-storage in 2017/18. Three models of potential utility responses to the shift are described: fight, flight, or innovate.

Hart, J. et al. (2016). *Small Thermal Energy Storage and Its Role in Our Clean Energy Future.* ACEEE. http://aceee.org/files/proceedings/2016/data/papers/3_262.pdf

This paper describes analysis of thermal energy storage projects in several states, and how they could improve efficiency, decrease peak load growth, defer distribution grid upgrades, integrate renewables and reduce pollutants. Also examines how such systems could be incorporated into demand response programs to maximize their value to utilities and customers.

Lazar, J. (2016). *Teaching the Duck to Fly. Regulatory Assistance Project*. http://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-teachingtheduck2-2016-feb-2.pdf

This report suggests a variety of ways to improve integration of renewable electric power and reduce load profile variations. This second edition includes discussions of battery options and new diagrams showing the effects on utility loading before and after each suggested strategy is implemented.

National Renewable Energy Laboratory (2017). *REopt: Renewable Energy Integration and Optimization.* https://www.reopt.nrel.gov

This is the homepage for the NREL REopt tool and related resources, including case studies of early applications. According to NREL, REopt is a techno-economic decision support model, used to optimize

energy systems for buildings, campuses, communities, and microgrids. REopt recommends an optimal mix of renewable energy, conventional generation, and energy storage technologies to meet cost savings and energy performance goals. It is compatible with popular Solar Advisor Model (SAM) project modeling software, but encompasses solar-plus options. A simplified tool is publicly available; more advanced applications require NREL technical support.

Neubauer, J. and Simpson, M. (2015). ***Deployment of Behind-the-Meter Energy Storage for Demand Charge Reduction.*** National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/63162.pdf

A study of the impact of solar plus lithium ion batteries for peak shaving. It found that under current rate structures, some customers could benefit, but benefits might not extend to the utility.

Palmintier, B. et al. (2016). ***On the Path to SunShot: Emerging Issues and Challenges in Integrating Solar with the Distribution System.*** National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/65331.pdf

One of a series, this report addresses strategies for grid-integration with increasing solar penetration, noting how storage and complementary technologies may be deployed to increase community solar value.

Sardi, J. et al. (2017). Multiple Community Energy Storage Planning in Distribution Networks Using a Cost-Benefit Analysis. ***Applied Energy*** **190:453-64.** http://doi.org/10.1016/j.apenergy.2016.12.144

This paper may help utilities plan the siting of utility-owned storage on the distribution grid, with PV. The strategy considers benefits, e.g., energy arbitrage, power generation, upgrade deferral, and VAr support, as well as costs. Several financial measures were calculated in a cost-benefit analysis.

Simpkins, T. et al. (2016). ***Optimal Sizing of a Solar-Plus Storage System For Utility Bill Savings and Resiliency Benefits.*** National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy17osti/66088.pdf

Presents a model and optimization method to size a solar and storage system to maximize resiliency benefits in the case of grid-service interruption.

Taylor, M. (2016). ***Is Battery Storage Cost-Effective for Utilities?*** **Washington. DC: Smart Electric Power Alliance.** https://sepa.force.com/CPBase__item?id=a12000000OLQKO4AAP

One of a growing list of resources from SEPA, this is a report on a utility survey, where 65% expressed interest in battery storage over other, related technologies. This brief notes the importance of early market-based applications, while acknowledging current economic limitations.

Weiss, J. et al. (2017). ***Electrification: Emerging Opportunities for Utility Growth.*** The Brattle Group. http://www.brattle.com/system/news/pdfs/000/001/174/original/Electrification_Whitepaper_Final_Single_Pages.pdf?1485532518

This report is an updated and expanded companion to Hiedik, R. et al. (2016) discussed in the Portals section above. It covers a broad range of technologies and flexible grid-operation strategies that could complement a high-penetration renewables portfolio across the U.S.

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The information, data, or work presented herein was funded in part by the Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy, under Award Number DE-EE0006905.