Solar+Storage
Board Learning Paper

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Energy Trust of Oregon

Preface

This paper is part of a series that describes a variety of topics identified by Energy Trust of Oregon's Board of Directors as potentially influential to the organization during the time period of its next strategic plan (2020-2024). This series of papers will educate and inform the Board about the potential impact of these topics and enable its Directors to better to assess risk, identify opportunity and guide the direction and goals of Energy Trust.

Remaining current on potentially significant and influential developments in the clean energy industry is critical to the fundamental role of the Board. These topics have been identified because of their potential to influence, impact or otherwise affect Energy Trust's ability to serve the ratepayers of Oregon and Southwest Washington. These papers should not be interpreted as policy proposals or recommendations for roles in which Energy Trust intends or desires to be directly involved.

Introduction

Energy efficiency is the cleanest, cheapest, and most important resource for the utilities and ratepayers of Oregon, and Energy Trust is the prime organization delivering that resource. Energy Trust also invests in clean, renewable energy generation and has supported the installation of more than 12,000 solar systems over the past 15 years. As costs for both solar and battery electric storage come down, a growing number of customers are choosing to install batteries as part of their solar systems or to add batteries to existing solar systems. For now, these "solar+storage" systems provide bill savings and backup power to the customer. In the future, these systems may present an opportunity to provide additional benefits for both individual customers and the utility grid as a whole.

This paper explores recent battery market and technology trends, potential applications and local policy considerations for solar+storage systems.

Solar+Storage definition

In this paper, **solar+storage** (S+S) refers to a solar photovoltaic (PV) system paired with battery electric storage, typically installed in the same location and using shared electrical components or controls. This paper focuses on distributed solar+storage systems installed at customer homes or business. However, there are many other types of energy storage systems, such as large flow batteries, pumped hydropower, thermal energy storage or compressed air systems. These systems fall outside the scope of this paper.

When configured such that it can **island,** or separate from the distribution grid and continue to run independently, a S+S system can be considered a **microgrid.** A microgrid, as defined by U.S. Department of Energy, is:

> "a group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.[1]"

Battery terminology

Battery storage can be characterized with a power rating (watts, kilowatts or megawatts) and a time rating, which refers to duration of discharge (generally expressed in hours). It is important to know both characteristics in order to understand appropriate applications of a battery. Multiplied together, the power and duration of a battery are its energy rating, which is expressed in kWh (kilowatt hours) or MWh (megawatt hours). For example, a battery rated to deliver 6 kW (kilowatts) for two hours of discharge would have an energy rating of 12 kWh. Alternatively, this same battery could discharge 4 kW for three hours or 2 kW for six hours. However, it could not provide more than 6 kW of power or discharge faster than its two-hour rating.

Technology and Market Overview

How does it work?

In the simplest S+S configuration, the battery absorbs excess generation from the solar PV system and then discharges this energy later, when it is needed. Some S+S systems allow the battery to charge from other sources in addition to the solar PV, such as from the grid or from another source of onsite generation.

Solar PV and batteries do require other technologies to make them work. These may include inverters, controls, isolating switches (to separate the system from the grid) or data acquisition systems. An **advanced solar+storage** system uses a microprocessor to control and optimize the use of the PV and battery to meet customer or utility goals. Systems may work independently with local controls or be **aggregated**, or grouped together

Why combine solar and storage?

In general, solar PV and batteries are complementary technologies that work well together in many settings. They are scalable, from small customer-sited systems to large, utility-scale projects. Additionally, they provide numerous services and can be used in various applications. They do not depend on fuel deliveries, making them ideal for resilient power applications.

Solar PV is a variable generation technology that has energy value (it produces energy) but little capacity value. In other words, by itself, a PV system cannot reliably supply needed power at a specific time, for example during peak demand hours. Storage, on the other hand, does not generate any energy, but once charged provides power when needed. Therefore, storage has relatively little energy value, but great capacity value. Used together, a S+S system can provide energy that is both renewable and more **dispatchable**, or available when needed.

Adding storage to solar also involves a few tradeoffs. Primarily, batteries add cost, complexity and losses to a relatively simple system. Storage is not 100 percent efficient, meaning some energy is lost while charging and discharging the battery. As discussed below, storage may either increase or decrease the financial value of solar system for a customer, depending on the use case and available utility rates.

System configurations

S+S systems can be set up in various configurations and locations: on the transmission grid, on the distribution grid or behind a customer meter. The latter is known as a **behind-the-meter** system. Utilities, customers or third parties can own systems. Most of the time, S+S will be **grid-tied**, meaning connected to the utility grid. This is important, because grid-tied systems can provide benefits both to the host facility and to the utility or the grid, for example through demand response programs. Customers who use S+S systems to go completely off-grid cannot provide such benefits.

One customer benefit of S+S systems is the ability to **island** or isolate the system from the grid in case of a grid outage. This is typically not something solar can do alone; solar systems are configured to go down if the signal from the grid is lost, as a precaution to protect the lives and safety of line workers[2]. Adding energy storage and isolating switches to a behind-the-meter system allows a S+S system to safely island during a grid outage, then continue to provide electricity to its host facility while the grid is down, and finally reconnect to the grid when grid power is restored.

Modern, advanced S+S systems have potential to receive signals from the utility or grid operator. In some regions of the United States, storage systems can participate in wholesale electricity services markets, such as frequency regulation markets (although small systems may need to be aggregated to meet market requirements). Several utilities are experimenting with aggregating customer-sited S+S systems for capacity and transmission savings, as well as resilience.[3]

Storage Industry Trends

Prices

Prices of lithium ion batteries have fallen 79 percent since 2010. Price declines are expected to continue, although not as steeply. Combined with the steep declines in solar prices, some analysts have predicted that behind-the-meter S+S will soon be competitive with retail electricity prices in numerous states.[4] Oregon, with relatively low power rates and average solar resource, is behind other parts of the country on this trajectory.

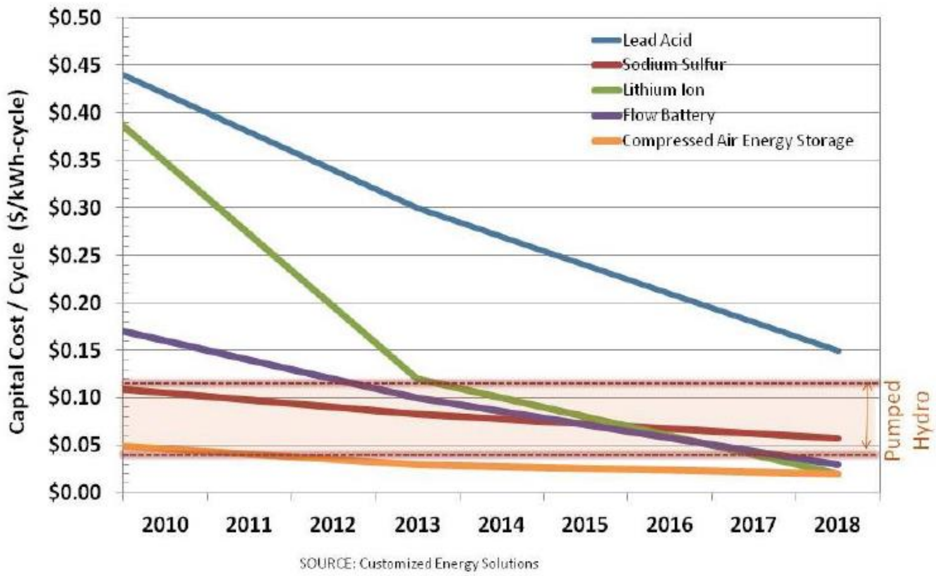

Figure 1: Massachusetts State of Charge report. Note that "The depicted levelized cost shown takes into account the total predicted cycle life, or the operational lifetime of the technology, and thus normalizes the capital cost over the entire lifetime of the project."

Chemistries

The current battery market is dominated by lithium ion technology. In Q4 2016, lithium ion batteries had a market share greater than 98 percent. Lithium enjoys a number of advantages, including that it serves the growing EV and consumer goods markets, which drive demand. As production capacity continues to increase, it is expected that prices will continue to fall.

There are other chemistries that may offer advantages over lithium for certain applications. Lead acid still has a place in the market, and there are up-and-coming chemistries such as advanced lead acid, which claims to combine the advantages of both lead and lithium, and flow batteries, offering significant advantages for certain applications. However, many analysts believe the industry is close to a point where lithium’s market share advantage could lead to “lithium lock-in,” meaning that competing technologies may not have the opportunity to prove themselves in the market.

Applications

Behind-the-meter S+S is useful in a wide variety of applications that can provide resilient power, power quality improvements, consumer cost savings and revenues, utility cost savings and revenues and grid services. Importantly, it is often possible (and economically necessary) to “stack” multiple benefits. However, no one system can provide all services simultaneously, and the advantages of benefit stacking must be weighed against its potential to reduce battery life by increasing the frequency of charge and discharge cycles. Therefore, value-stacking calculations must be made on an individual project basis, taking all variables into account.

As shown in Figure 2 below, the types of applications that can be stacked depend on the location of the solar+storage system. Behind-the-meter systems have the potential to offer a full range of benefits to customer, utility and grid. Systems located on the utility grid offer a narrower range of services. However, behind-the-meter resources are typically more costly due to economies of scale, and require tradeoffs to balance utility and customer benefits. In particular, some services that batteries provide can interfere with the ability of a system to provide other services. For example, if resilience is a primary objective, the customer would need to reserve stored energy for an unexpected grid outage. In this situation, the amount of battery capacity available for other services would be restricted.

Certain grid-side services may require direct control of the S+S system by the utility. While this is possible with behind-the-meter storage, it is dependent on additional communications technology and an agreement between the customer and utility on how the system will be used. It is also possible for S+S to provide grid services without active control. For example, utilities may be able to achieve demand reduction through pricing signals, such as time-of-use rates, or with incentives for programming systems to reduce load during typical peak-demand hours.

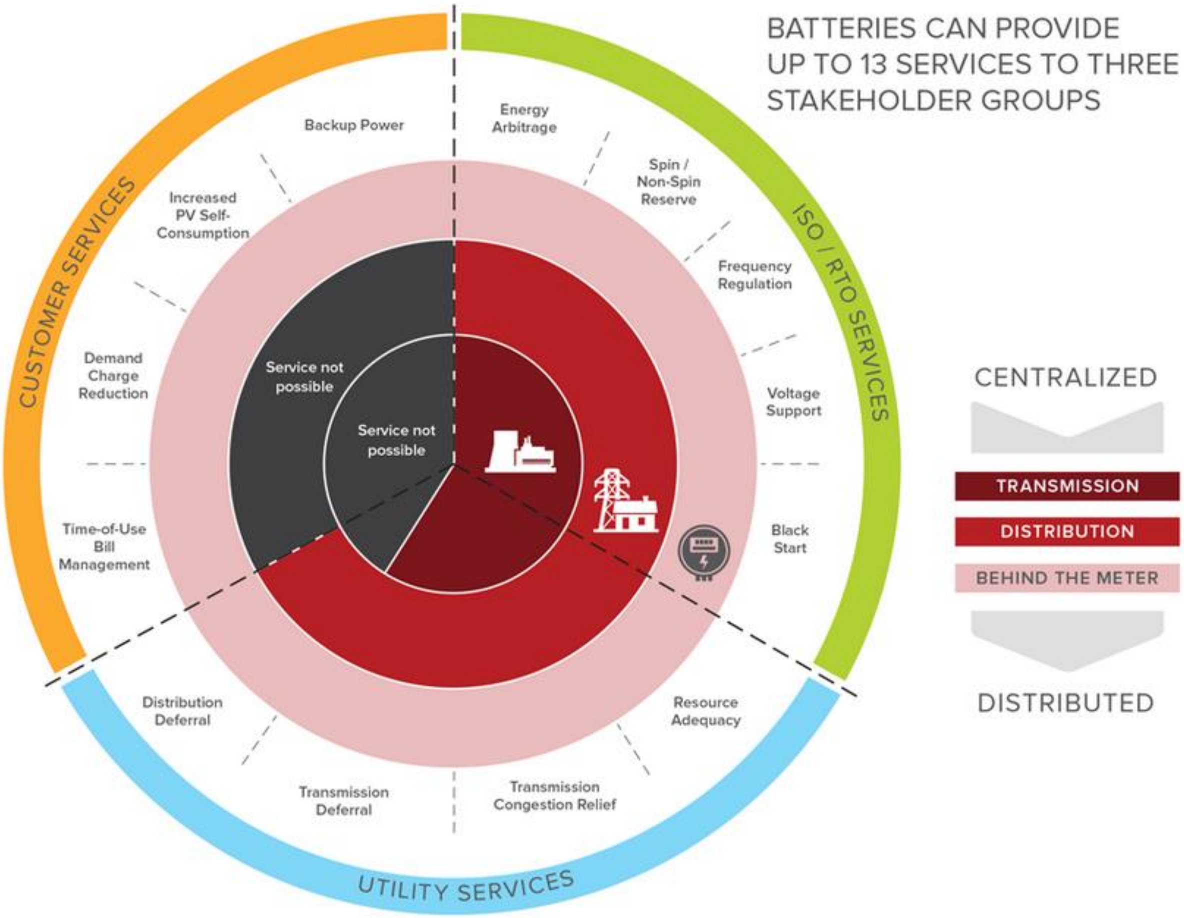

Figure 2: RMI The Economics of Battery Storage. Storage behind the meter can provide more benefits than storage on the transmission or distribution grids.

Use Cases for Solar+Storage

Customer cost savings and revenues

Compared to a solar system on its own, a S+S system may or may not provide additional utility bill savings.

Savings for commercial customers are often based on demand charge management. Solar PV lowers the energy portion of a customer's bill by reducing the amount of electricity the customer must purchase from the grid. However, solar alone cannot be relied on to reduce the customer's demand charge, which is calculated based on the customer's highest demand for electricity each month. By adding storage, the customer can shift solar generation to peak demand times, thus capping peak demand and lowering demand charges. In markets where demand charges are higher, such as California, the Northeast and parts of the Midwest, these savings may be sufficient to drive a S+S market.[5] Residential customers do not generally pay demand charges and therefore cannot make use of solar+storage for these savings.[6]

Customers can also make use of S+S for energy savings when they have a time of use (TOU) rate structure with a wide enough spread between high and low rates. If utilities offer demand response (DR) programs, S+S customers may be able to participate. Theoretically, a S+S system could be used for both DR and demand charge management simultaneously, depending on available utility rates and offerings.

In areas where changes to net metering rules or rates cause reductions in bill savings for solar customers, the addition of energy storage may help to maintain bill savings by allowing customers to self-consume more solar energy, thereby offsetting the purchase of electricity at retail rates.

In some states, customers can sell services to a market for grid services. This allows customer to enhance revenues for behind-the meter S+S by selling capacity and/or grid services, such as frequency regulation to a utility or grid operator. Typically, these are commercial or industrial customers who have a large S+S resource primarily for the purpose of resilience and/or demand-charge management. Smaller commercial and residential customers may not be able to participate in these markets unless an aggregator is available to bundle and sell their services.

Resilient power

S+S that can island from the grid is ideal for resilient power provision because it is clean, fuel independent and can scale to meet various critical load sizes. S+S may also provide year-round cost savings and revenues, if TOU rates, demand-charge reduction opportunities or other forms of compensation are available to customers. Diesel generators, by comparison, are polluting, fuel dependent and represent a sunk cost that will never produce revenues or cost savings.

Resilient power can be provided by S+S systems that either are located behind the customer meter or located on the utility distribution system. Examples of the latter include the Green Mountain Power microgrid in Rutland, Vt. and the Sterling Municipal Light Department project in Sterling, Mass. It currently is not possible to monetize resilience, but it does have a value and this value should be taken into account when considering the costs and benefits of a proposed S+S system.

As discussed in the Community Resilience learning paper, the potential for a Cascadia subduction zone earthquake poses a particularly difficult resilience problem, with some coastal areas projected to be out of power and inaccessible for months following a major earthquake. In these conditions, fuel for backup generators is expected to be extremely limited. S+S installations would provide an alternative source of power, allowing fuel to be rationed and reserved for the most critical infrastructure. Even if such a disaster occurred during a cloudy winter month, S+S could limit the consumption of precious fuel reserves and make power more widely available at emergency management sites, shelters, gathering places, communication nodes and homes.

Utility cost savings

The opportunity for utilities to realize cost savings and revenues from S+S depends on an individual utility's needs and the regulatory environment in which it operates. For some utilities, T&D investment deferral will be an attractive application. For others, capacity and peak shifting will be top priorities. In some cases, impending generator retirement may present an opportunity; or, resilience concerns may drive S+S deployment planning.

In the regulated power markets of the Northeast, the best economic case for utility S+S to date has been utility capacity and transmission cost savings, as demonstrated by Green Mountain Power and Sterling Municipal Light Department.[7] This model is now being adopted by numerous other utilities and electricity co-ops in the New England wholesale market.[8] At current prices, these projects have payback periods of six years without subsidies. Other use cases for utilities include arbitrage (buying and selling energy on the market), frequency regulation, renewables integration, ramping (matching changes in load), transmission and distribution (T&D) investment deferral, replacement of retiring generation resources and resilience.

Some utilities are beginning to experiment with putting S+S behind customer meters. By remotely dispatching customer-sited systems, utilities can achieve the same capacity and transmission cost savings as would be achieved with a system on the distribution grid, while providing additional savings and resilience for customers. For an example of such a program, see the current Liberty proposal in New Hampshire[9]. Notably, Southern California Edison recently exceeded its mandated 50 MW storage procurement by procuring 260 MW, of which 160 MW was distributed, rather than centralized storage.

T&D deferral can be a good utility use case but is very location-specific. For example, the Brooklyn Queens Demand Management Program will defer a $1 billion substation upgrade using $200 million in load reduction strategies including customer demand management and storage. The program has been so successful that Consolidated Edison is now expanding it.[10]

In Oregon, Portland General Electric and Pacific Power are investigating savings opportunities and use cases for storage through active Oregon Public Utility Commission (OPUC) dockets, as discussed below.

Grid services

The category of grid services can refer to many different things, including ancillary services, a grouping of services necessary to maintain grid stability and security. S+S systems are often good at providing grid services, and can do so even from behind the customer meter if appropriate interconnection and controls are in place.

The value of grid services, and the ability of distributed resources to provide them, varies greatly from service area to service area. These services include capacity, frequency response and regulation, ramping and similar services. The increasing competitiveness of S+S in these areas can be seen in the fact that S+S is increasingly competitive with gas peaker plants, which provide similar services. S+S is already cost effective compared to gas peakers in select markets, and some analysts project that within 10 years, S+S will be less expensive gas peakers in most markets[11].

In addition to market or regulatory rules that allow distributed resources to provide grid services, aggregators are often needed to provide market access to smaller, behind-the-meter resources. Aggregation can be performed by a utility or a third party company. In either case, the purpose is to bundle together the capacity of numerous small resources to create a larger cumulative resource. The key to aggregation is the ability to remotely dispatch the small systems that are being aggregated, and to share the resulting cost savings or revenues among all participants.

Third-party aggregators have arisen in some regulated wholesale markets where pricing is transparent and barriers to market entry have been removed. Third party aggregation is more difficult in areas where pricing is opaque and ancillary services markets either do not exist, or remain closed to third-party providers. In these areas, utilities may serve as aggregators for their customers.

Policy Considerations in Oregon

Federal policy and incentives

S+S is eligible for the federal Investment Tax Credit (ITC) and associated accelerated depreciation. Together, these two incentives can represent 60 percent of the installed costs of a project. Based on I.R.S. private letter rulings, storage added to existing residential solar is also eligible for the ITC.[12] However, these systems must charge 100 percent from the associated solar in order to receive the tax credit. For commercial systems, batteries may be charged less than 100 percent from solar, but this will result in the system receiving less than the full ITC. For these commercial systems, there is a 75 percent cliff for renewable charging, after which no portion of the ITC may be taken for storage. For more information, see guidance from NREL[13] and Deloitte.[14]

OPUC dockets

In 2015, Oregon House Bill 2193 tasked the OPUC with implementing a storage mandate for Portland General Electric and Pacific Power. PGE has proposed to procure 39 MW of storage, the maximum amount allowed under the law. PGE's proposal, now under review in docket UM 1856, includes a mixture of utility-scale batteries, micro-grids tied to pre-existing distributed generation and residential behind-the-meter storage[15]. Pacific Power's proposal is more modest: two utility-scale installations totaling 4 MW (docket UM 1857[16]). As part of the dockets, the utilities have evaluated various applications of storage, providing useful information to the OPUC on the opportunities and value of energy storage in Oregon.

In a parallel docket, UM 1716, the OPUC is investigating the resource value of solar (RVOS). The OPUC has identified 11 value or cost elements that make up the resource value, primarily: energy, generation capacity, transmission and distribution capacity and line losses. The resource value methodology includes a placeholder for grid services, valued at zero for now. In the order that adopted the RVOS elements, the OPUC noted that there are currently few S+S systems, but the RVOS methodology could be modified in the future to incorporate values provided by storage[17]. The OPUC has not yet determined how RVOS will be applied, or whether the RVOS will be a single value per utility or vary by location or type of system.

Utility distribution system planning

Distribution system planning may be very important for S+S deployment, especially for deployment on the distribution grid and for behind-the-meter projects, which will need to connect with the distribution grid. Because the grid was not designed for two-way flows of power, a variety of upgrades may be needed to enable distributed energy resource (DER) deployment to scale up and provide all the benefits of which it is capable. Adding the flexibility provided by storage may help mitigate constraints in areas where the utility has limited "hosting capacity" for local generation. Along with Energy Trust's learning paper on DER, numerous reports are available on this subject.[18]

Energy Trust Impacts and Connections

Energy Trust plays an active role in Oregon’s solar market, helping customers install clean energy systems at their homes and businesses. Beyond financial incentives, Energy Trust also provides education, consumer protection and quality management services for customers, and business development and training for solar contractors. S+S systems have always been included in Energy Trust’s standard solar incentive program, receiving the same incentives and services as other projects. However, the program has not considered the additional costs of storage in its above-market cost analysis used to set standard or custom incentive levels.

Interest from Energy Trust customers and trade allies in S+S has increased significantly. In 2017, 85 residential and five non-residential solar applications included storage. This was up from 15 S+S applications in 2016.

S+S is of particular interest for municipalities working on emergency preparedness. For example, the City of Portland is leading a working group exploring how to use S+S to meet community resilience needs in the aftermath of a Cascadia subduction earthquake. Energy Trust staff joined team members from the City, along with Multnomah County, Portland General Electric and Pacific Power to work on S+S solutions for resilience at the 2017 Rocky Mountain Institute eLab Accelerator conference.

Energy Trust is collaborating with the National Renewable Energy Lab (NREL) and Clean Energy Group to perform analysis of the resilience capabilities and financial benefits of S+S for 10 specific sites. Each of the sites serves the low-income community. Because a home or building's hourly load profile is unique to the equipment installed and the manner in which the home or building is operated, the costs and benefits of S+S systems are also unique to each site. In addition to this research, the Energy Trust Solar program is encouraging solar trade allies and customers to explore this technology by offering incentives for S+S feasibility assessments. These assessments provide customers with a preliminary system design and financial analysis so that they can gain an understanding of the cost and benefits of S+S for their site. In anticipation of the growing demand, Energy Trust staff are coordinating across the Solar, New Homes and New Buildings programs to identify opportunities early in the design process to incorporate resilience and prepare sites to be "solar plus storage ready."

Based on feedback from the OPUC in its 2016 review of solar incentive programs, the Solar program is working to find ways that solar systems can provide additional benefits to the utility grid. This goal is reflected in the Solar program's approved 2018-19 Action Plan and includes activities focused on S+S:

> ***Support applications of solar that provide higher utility value***
>
> - *Explore and test ways to deploy solar to meet peak energy needs, including pairing with energy efficiency, storage or flexible loads. Test methods to influence adoption of solar systems with more advanced controls for storage or flexible loads…*
> - *Develop communication materials to address growing customer interest in solar plus storage.*

Summary/Conclusions

S+S is a hybrid technology that can provide greater benefits than either solar or storage alone. S+S is finding a growing market, both behind the meter and on the utility grid. Rapid price declines and changing market and regulatory structures mean that S+S is increasingly attractive for a number of applications. One key application for Oregon is resilience.

S+S can provide multiple benefits when located behind the customer meter. There are mechanisms for sharing benefits between customers and the utility, but this may involve trade-offs between customer and utility interests.

S+S still faces numerous barriers including technical, market and informational barriers. Energy Trust is already working with utilities, trade allies and customers to help address some of these barriers in Oregon. Stakeholders may need to consider other policy and regulatory barriers over time, including appropriate valuation of S+S as a flexible, distributed energy resource.

About Energy Trust of Oregon

Energy Trust of Oregon is an independent nonprofit organization dedicated to helping utility customers benefit from saving energy and generating renewable power. Our services, cash incentives and energy solutions have helped participating customers of Portland General Electric, Pacific Power, NW Natural, Cascade Natural Gas and Avista save on energy bills. Our work helps keep energy costs as low as possible, creates jobs and builds a sustainable energy future.

Prepared by staff of Energy Trust and the Clean Energy States Alliance.

About Clean Energy States Alliance

Clean Energy States Alliance (CESA) is a national, nonprofit coalition of public agencies and organizations working together to advance clean energy. CESA members—mostly state agencies—include many of the most innovative, successful, and influential public funders of clean energy initiatives in the country. CESA works with state leaders, federal agencies, industry representatives, and other stakeholders to develop and promote clean energy technologies and markets. Learn more at www.cesa.org.

[1] https://building-microgrid.lbl.gov/microgrid-definitions
https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf

[2] Solar inverters are required to disconnect from the grid or shut down during a grid outage. Typically, this means grid-tied solar systems without storage are unavailable during an outage. As an exception, certain solar inverters allow customers to power a single off-grid power outlet during a daytime outage. For example, inverter manufacturer SMA offers an add-on backup power outlet called the Secure Power Supply, http://www.smainverted.com/how-to-explain-secure-power-supply-to-homeowners/

[3] i. Such “virtual power plant” arrangements have been tried by Green Mountain Power in VT, Southern California Edison in CA, and Glasgow Electric Plant Board in KY, among others. Currently, the South Australia government and Tesla are planning the world's largest virtual power plant: solar+storage will be installed in nearly 50,000 South Australian households. Aggregated, these small S+S systems would deliver 250 megawatts of dispatchable energy, comparable to a traditional gas or coal plant. In the trial phase of the project, Tesla will install the systems in 1,100 public housing rental units, at no cost to the residents.

[4] https://www.rmi.org/wp-content/uploads/2017/04/RMIGridDefectionFull_2014-05-1-1.pdf and https://www.rmi.org/wp-content/uploads/2017/04/2015-05_RMI-TheEconomicsOfLoadDefection-FullReport-1.pdf

[5] A report by Clean Energy Group and NREL shows that millions of commercial customers across the country are paying demand charges in excess of $15/kW, which may be sufficient to make batteries a cost-effective solution for demand charge management. https://www.nrel.gov/docs/fy17osti/68963.pdf

[6] The current net metering docket in MA has explored numerous technical solutions to allow customers with storage to net meter while preventing “gaming” of the net metering program. It has also revealed that utilities would like to claim the capacity attributes of BTM S+S systems and sell them into the regional forward capacity market; however this would severely restrict the ability of commercial customers to engage in DCM due to competing claims on battery capacity. This is a battle likely to be fought through a number of dockets.

[7] http://www.sandia.gov/ess/docs/journals/SterlingMA_2017PES_SAND2017-1093.pdf

[8] Because prices for capacity and transmission services are set for the entire Independent System Operator (ISO) wholesale market, market values for these services are the same in all six New England states.

[9] https://www.transmissionhub.com/articles/2017/12/liberty-utilities-seeks-approval-in-new-hampshire-for-battery-pilot-program.html

[10] https://www.utilitydive.com/news/straight-outta-bqdm-consolidated-edison-looks-to-expand-its-non-wires-appr/447433/

[11] https://www.greentechmedia.com/articles/read/battery-storage-is-threatening-natural-gas-peaker-plants#gs.M4JphL0

[12] https://www.greentechmedia.com/articles/read/irs-says-that-batteries-can-take-the-federal-tax-credit#gs.4QcdMhA

[13] https://www.nrel.gov/docs/fy18osti/70384.pdf

[14] https://www.cleanegroup.org/webinar/financing-solarstorage-with-federal-tax-credits/

[15] http://edocs.puc.state.or.us/efdocs/HAH/um1856hah92141.pdf

[16] http://edocs.puc.state.or.us/efdocs/HAH/um1857hah142659.pdf

[17] OPUC Order 17-357 from September 15, 2017. The possible application of RVOS to solar with storage is discussed on page 15. http://apps.puc.state.or.us/orders/2017ords/17-357.pdf

[18] PNNL, "State Engagement in Electric Distribution System Planning" (https://emp.lbl.gov/sites/default/files/state_engagement_in_dsp_final_rev2.pdf); Synapse, "Distribution Systems Planning"(http://www.synapse-energy.com/sites/default/files/Distribution-System-Planning.pdf); MN PUC, "Integrated Distribution Planning" (https://energy.gov/sites/prod/files/2016/09/f33/DOE%20MPUC%20Integrated%20Distribution%20Planning%208312016.pdf).