PACIFIC POWER
A DIVISION OF PACIFICORP

825 NE Multnomah, Suite 2000
Portland, Oregon 97232

December 18, 2020

VIA ELECTRONIC FILING

Public Utility Commission of Oregon
Attn: Filing Center
201 High Street SE, Suite 100
Salem, OR 97301-3398

Re: UM 1857—PacifiCorp's Final Phase I Report on Community Resiliency Pilot

PacifiCorp d/b/a Pacific Power (PacifiCorp or the Company) submits for filing its final report on Phase 1 of the Community Resiliency Pilot in the above referenced docket.

Pilot Project 2—Community Resiliency Pilot

In the stipulation filed in docket UM 1857 by PacifiCorp on July 18, 2018, and adopted by the Commission in Order No. 18-327 (September 4, 2018), PacifiCorp committed to developing a Community Resiliency Pilot (Pilot Project 2) to provide technical and financial assistance to study and deploy energy storage resources to facilities critical to emergency response or disaster recovery. The stipulation laid out a phased approach for Pilot Project 2, beginning with a consultant-led technical assistance concept resulting in a limited number of initial studies (Phase 1), followed by financial assistance for the installation of energy storage resources for up to four critical facilities (Phase 2).

In Order No. 18-327, the Commission authorized PacifiCorp to recover up to $200,000 in Phase 1 of Pilot Project 2. After the completion of Phase 1, but prior to beginning Phase 2, PacifiCorp will file a revised plan estimating the costs, benefits and anticipated learnings associated with Pilot Project 2 for Commission approval and seek Commission authorization to recover costs associated with Phase 2.

After a competitive procurement process, PacifiCorp awarded the technical assistance contract for Pilot Project 2 to TRC in August 2019. The attached report represents the final report which details key learnings from Phase 1 of Pilot Project 2, based on the technical assessment work it was able to perform. The report focuses on lessons learned through preparing the individual reports, a high level estimate of potential utility benefits, as well as insights learned about the Oregon storage market from outreach to the storage industry.

PacifiCorp intends to solicit input from stakeholders and use the key learnings identified in this final Phase 1 report to develop a revised plan for Phase 2 of Pilot Project 2. PacifiCorp expects to be prepared to file a revised Phase 2 plan for Commission approval by the end of January 2021.

Please direct any informal correspondence and questions regarding this filing to Cathie Allen Regulatory Affairs Manager, at (503) 813-5934.

Sincerely,

Etta Lockey
Vice President, Regulation

Enclosures

COMMUNITY RESILIENCY PILOT

Phase 1 Final Report
December 2020

Submitted By:

TRC

Submitted To:

PACIFIC POWER

POWERING YOUR GREATNESS

About

For over 100 years, Pacific Power has provided Oregon customers with safe, affordable, and reliable electricity service, but sometimes power disruptions occur. The cause of these potential disruptions can range from car-hit-pole accidents to a Cascadia Subduction Zone earthquake. Acknowledging that a power disruption may be more than just an inconvenience for facilities critical to emergency management and disaster recovery, Pacific Power developed the Community Resiliency Pilot to help customers at these critical facilities expand their understanding of battery energy storage and how they may be able to meet the resiliency needs of the communities they serve with battery energy storage. Community energy resilience is defined as the ability for a community to withstand "high-consequence, low-probability" events and to regain normal operational activity after such events occur. In addition to examining the benefits of battery energy storage for critical facilities, the Pilot explored the available technologies, costs, use cases, and feasibility associated with installing battery energy storage at those sites.

Disclaimer

Costs included in this report are initial planning estimates for equipment and installation and may vary from actual quotes provided by contractors.

1. Table of Contents

2. Executive Summary

Background

In 2019, Pacific Power launched the Community Resiliency Pilot to support efforts for a replicable, community-scale planning process for the identification and prioritization of sites for solar-plus-storage systems that can assist communities during potential long-term power outages and improve resiliency in local communities.[1] The Pilot defines community resiliency as the ability for a community to withstand high-consequence, low-probability events and to quickly regain normal operations after such events occur. The Pilot seeks to explore the use of available technologies to address resiliency needs of select facilities critical to emergency response or disaster recovery, while learning about the technologies, costs, benefits, use cases, and feasibility associated with customer-sited battery energy storage. This preliminary report shares the following information:

- The value streams that battery energy storage may bring to participants in the program, society, and the utility when storage systems are implemented at critical facilities
- The study approach and technical feasibility of battery energy storage systems for four sites in Oregon
- The third-party vendor landscape in Oregon and how certain market drivers can change that outlook
- Recommendations for future program considerations in light of findings from the site evaluation studies

Approach

The Pilot approach started with site selection and criteria development to identify and recruit key sites. After recruitment, the Community Resiliency Pilot team began data collection, and scheduled site audits with site participants. The Pilot team used a desktop review process for initial analysis prior to the site audits. This desktop review enabled a more thoughtful walkthrough with participants, ensuring key verification of inputs into the analysis. After returning from the site audits, the Pilot team completed analysis for each site participant and drafted a final site evaluation report. After those site reports were shared with the pilot participants, the Pilot team held follow-up phone conversations to review the key findings.

This process focused on lithium-ion (Li-Ion) battery technology and included investigation into key components that would help provide information to customers to determine financial and technical feasibility to implement battery energy storage at their facilities.

The technical investigation included the following:

- **Resiliency scenarios.** The Pilot team developed scenarios from standard (conventional fossil fuel backup generation) to comprehensive (maximizing solar plus storage) to show the varying degrees of resiliency that a customer could achieve.
- **Cost Investigation.** Costs explored included capital, operation, and maintenance for both existing backup generation, battery energy storage, and solar systems.

[1] Pacific Power hired TRC in 2019 to assist in developing and implementing the Community Resiliency Pilot, together they comprise the Pilot team referenced in this report.

- **Critical load identification**. The Pilot team conducted critical load identification for each site to understand the loads that would be required to run during a disaster event.
- **Interconnection considerations.** Discussion included the interconnection requirements associated with connecting to the Pacific Power grid.
- **Overall feasibility.** The feasibility evaluation analyzed how well a battery energy storage system could provide the following services and benefits to the site: (1) ability to provide backup power generation and community resiliency, (2) ability to reduce carbon footprint, and (3) ability to reduce energy costs.[2]

Valuing Behind the Meter (BTM) Battery Energy Storage Systems

Battery energy storage can provide various benefits to both the customer and the grid, which are not necessarily mutually exclusive. In fact, these benefits can be stacked to enable a single system to capture multiple value streams. Accurately capturing the stacked benefits of battery energy storage requires detailed analysis of both the operational characteristics of the battery and the nature of the value streams it captures. The Pilot team explored the relevant benefits that could be provided by BTM Li-Ion battery energy storage applications through the lens of the customer, the utility, and society. Furthermore, to understand the benefit values at scale, the Pilot team chose also to investigate what a BTM battery energy storage program could be in 10 years, assuming the same participation rates as the Pacific Power Oregon Blue Sky solar program.

The outcome of this exploration was that battery energy storage could yield the following results:

- Total value for all participating customers of between about **$1 million and $6 million** over a ten-year period.
- Total grid services value to the utility over a ten-year period of between **$3 million and $20 million.**
- Total greenhouse gas (GHG) reductions from all participating customers of between about **3,890 and 7,775 tons of carbon dioxide (CO_2)** over a territory-wide two-week outage.
- Total community resiliency value from all participating customers of between about **$600,000 and $3 million** over a territory-wide two-week outage.

Pacific Northwest Battery Energy Storage Market

To understand greater detail regarding the BTM battery energy storage market in the Pacific Northwest, the Pilot team reached out to various actors that provide BTM services to understand the opportunities and barriers to offering storage to commercial customers in Oregon. The Pilot team designed questions to reveal each vendor’s experience with commercial-scale Li-Ion battery energy storage, their current product and service offerings, and each vendor’s perceptions of the Oregon commercial storage market at-large.

The vendor investigation revealed that the Oregon market for commercial-scale storage is in its infancy. Structural factors including inadequate incentives and unfavorable commercial electricity rates are delaying growth in the Oregon market. In addition, vendors operating in Oregon do not have access to battery energy storage systems appropriately sized for many of their clients’ needs. Multiple vendors

[2] Site specific results are included in Appendix E of this report.

want to participate in discussions that could help utilities design long-term solutions that encourage the adoption of storage in commercial settings.

Lessons Learned

The Community Resiliency Pilot uncovered key lessons learned, revealing several steps that may facilitate the successful expansion of a Community Resiliency program and the development of a BTM battery energy storage program for Pacific Power customers.

- Tie technical assistance to funding opportunities to ensure follow-through and adoption of technical recommendations.
- Expand the Community Resiliency Pilot to a broader program to unlock societal and utility benefits.
- Adopt effective policies, systems and processes to enable greater resiliency value and enable all the benefits of battery energy storage.
- Carefully consider the outage duration that a battery energy storage system is being designed to address.
- Continue to conduct virtual site audits when possible to alleviate unnecessary visit costs and keep customers safe.

3. Introduction

The Pacific Northwest, like many other regions around the country and world, is facing increased risk from hotter and longer wildfire seasons, more intense storms, droughts, flooding, and more. In the Pacific Northwest, we also live with reality of the looming Cascadia Subduction Zone earthquake—known regionally as *the big one*.

> *In the Pacific Northwest, the area of impact will cover some hundred and forty thousand square miles, including Seattle, Tacoma, Portland, Eugene, Salem (the capital city of Oregon), Olympia (the capital of Washington), and some seven million people.*[3]

Additionally, in response to catastrophic wildfires in recent years, utilities up and down the West Coast are adopting and implementing public safety power shutoff policies to deenergize power lines in certain areas and under limited circumstances to mitigate for heightened fire risk.

To prepare for these natural disasters, Pacific Northwest utilities, including Pacific Power, have taken action to improve the resiliency of vulnerable communities. The concept for this Pilot idea originated during City of Portland's Renewable Resilient Power for Portland working group,[4] which sought to improve resiliency in local communities. Resiliency issues were brought into closer focus by the recent 2020 wildfires; this work has taken on new momentum and importance in light of those challenges, presenting an opportunity to provide critical facilities in wildfire zones and facilities providing services to evacuees during disasters with essential battery storage energy backup power.

In 2019, Pacific Power launched the Community Resiliency Pilot[5] to explore the role that battery energy storage can play in expanding the resiliency of the communities it serves in Oregon. The Pilot defines

[3] Kathryn Schulz, "The Really Big One," New Yorker, July 13, 2015.
[4] "eLab Accelerator 2017: Renewable Resilient Power for Portland (R2P2)," Rocky Mountain Institute, accessed December 11, 2020, https://rmi.org/our-work/electricity/elab-electricity-innovation-lab/elab-accelerator/elab-accelerator-2017-teams-r2p2/.
[5] "Community resiliency programs," Pacific Power, accessed December 11, 2020, https://www.pacificpower.net/resiliency.

community resiliency as the ability for a community to withstand high-consequence, low-probability events and to regain normal operational activity after such events occur.[6] Battery energy storage can provide a solution for a community to keep a critical facility operating when the power grid shuts down during a short- or long-term power outage. This Pilot focused the investigation on Li-Ion battery technology, which is often paired with solar systems.

Within this framework, the Pilot team sought to identify available Li-Ion battery and associated technologies to address resiliency needs of select facilities critical to emergency response or disaster recovery, while gaining insight into the feasibility, costs, benefits, and use cases associated with this type of customer-sited battery energy storage. Li-Ion batteries were determined to be the most applicable technology based on its commercial availability, high cycle life, high energy density (and therefore minimal footprint), and flexibility to operate across a number of short and deep cycle applications.

This report shares the following information:

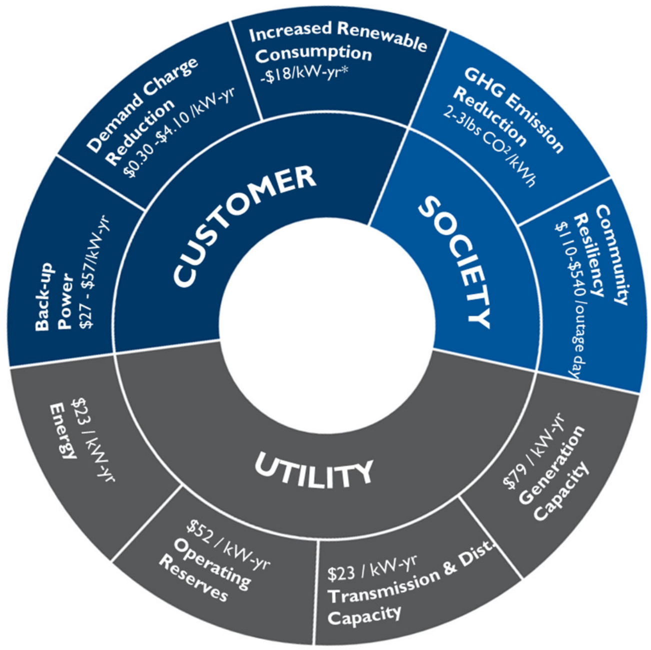
- Value streams that battery energy storage could bring to participants in the program, society, and the utility when systems are implemented at critical facilities
- Study approach and technical feasibility of storage systems for four sites across Oregon
- Third-party vendor landscape in Oregon and how certain market drivers can change that outlook
- Recommendations for future program considerations in light of findings from the site evaluation studies

4. Valuing BTM Battery Energy Storage Systems

Li-Ion battery energy storage can provide various benefits to both the customer and the grid, which are not necessarily mutually exclusive. In fact, these benefits can be stacked to enable a single system to capture multiple value streams. The availability of benefits varies depending on a number of factors, including the state regulatory landscape and utility in question; some of these benefits are currently more prominent than others in in Pacific Power's Oregon territory. While pursuing certain benefits may not be feasible today for BTM battery energy storage projects in the Pacific Northwest, the market is evolving quickly, ensuring that other benefits will be possible in the future.

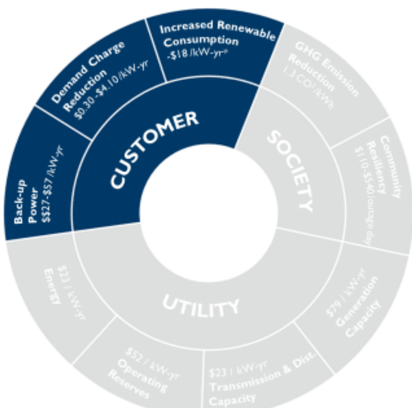
The Pilot team explored the relevant benefits of BTM Li-Ion battery energy storage through the lens of the customer, the utility, and society. Figure 1 below illustrates the different values attributable to customers, the utility, and society. The team normalized these values by avoided costs per kilowatt (kW) per year. However, societal benefits are shared as avoided emissions as well as avoided dollar costs.

[6] Anna Chittum and Grace Relf, "Valuing Distributed Energy Resources: Combined Heat and Power and the Modern Grid," American Council for an Energy Efficient Economy White Paper, April 2018, https://www.aceee.org/sites/default/files/valuing-der.pdf.



**Due to current NEM tariff, no incentive exists to increase self-consumption.*

Figure 1: BTM Storage Value Wheel



Value to Customers

The Community Resiliency Pilot demonstrated what it will take to keep a community's critical facility online and operating when the power grid shuts down. This involves integrating battery energy storage and associated technologies with existing resiliency resources on site to support critical operations during an outage. Under the primary use case of the Pilot, communities with critical facilities that have backup power during emergency events are more resilient during both unplanned and utility-planned outages. During normal operations, distributed battery energy storage has the potential to contribute to a more flexible grid, capable of accommodating new and/or increasing loads from electrification efforts, electric vehicle adoption, summer air conditioning usage, and more. The customer may see additional values in the form of long-term reduced energy costs and reduced carbon footprint during normal operations.

Backup Power

Battery energy storage provides a more resilient back-up system than a standard back-up generator because it reduces customer's dependency on fuel deliveries and infrastructure corridors that provide relief services during disaster events. Battery energy storage and solar components can reduce or eliminate run time and fuel usage of the backup generator, resulting in fuel cost savings and reducing the risk of a failure of fuel supply occurring. After analyzing what size and type of battery energy storage system—paired with the existing back-up generator and any new or existing solar—would be required to keep the customer's facility online during a two-week outage[7], the Pilot team concluded that fuel costs could be reduced by about 70 – 80 percent in most instances, compared to just using a backup generator for a two-week outage. Depending on the fuel, this equates to **about $27/kW-yr to $57/kW-yr of generator capacity per two-week outage per year** (see Appendix B, Determining Backup Power Value section for more details).

Demand Charge Reduction

Many of the BTM battery energy storage systems deployed to date in the United States have been designed to provide utility bill cost reductions for customers, typically through demand charge management and/or time-of-use (TOU) cost management. However, in the Pacific Northwest broadly, and in Pacific Power's Oregon service territory specifically, most of these value streams are minor at best. In Pacific Power territory, commercial utility rates are primarily tiered volumetric energy consumption structures with little to no demand charges, so bill cost avoidance applications alone for battery energy storage are challenging to justify at this time.

Demand charge management, sometimes called peak shaving or load shifting, involves dispatching a battery's stored energy to level demand (kW) use to reduce the associated charges on utility bills. The battery energy storage system is recharged during hours when the load is much lower, allowing the facility to stay below a demand limit and maintain cost savings. Due to inherent electrical losses of battery energy storage systems, more energy is always required to charge the battery than can be discharged. Therefore, total bill savings may come from a combination of demand charges and the cost differential between the charge and discharge energy inherent in TOU rates, but also must take into account the losses.

In areas with high demand charges and TOU rates, the added energy costs from charging the battery energy storage system have a relatively insignificant effect on the energy cost savings. However, the cost of the additional energy required to charge the system may outweigh any demand savings achieved in some instances. This is the case in Pacific Power territory, where there are low demand rates and TOU rates that provide limited benefits to shift to off-peak usage. For the Pilot sites, average demand savings ranged between **$0.30/kW-yr and $4.10/kW-yr**. The average rate depended on the tariff and the demand use profile. Those sites on a small commercial tariff, such as Schedule 23, and with existing solar, had the lowest average energy savings. This is because of the relatively low demand charge components in the tariff and the lower demand profile at the site due to the impacts of the solar.

Increased Renewable Self-Consumption

Pacific Power's Net Metering tariff (Schedule 135) credits customers for excess renewable production on a per kilowatt-hour (kWh) basis, to be applied at the full retail rate for each rate component on the bill that uses kWh as the billing determinant. If monthly credits are greater than applicable costs, those credits can be carried forward to the next billing month.

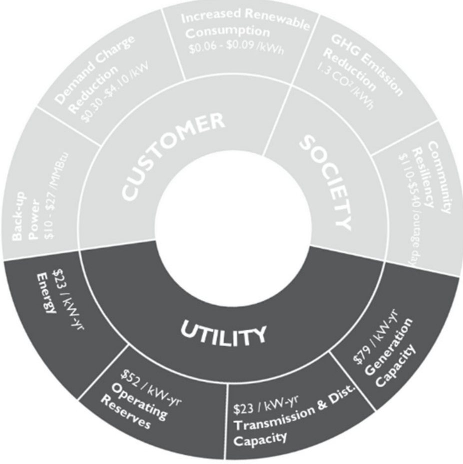
Depending on the tariff, the average relevant energy rates for the Pilot sites were between about $0.07/kWh and $0.10/kWh. With full retail rate net metering, the value of any excess renewable energy is credited at that same rate.

Because a battery energy storage system inherently has efficiency losses, the discharged energy will be less than the amount of energy required to charge the system. Therefore, with a non-TOU rate

[7] The Pilot team investigated a two-week duration outage as recommended by Oregon's Office of Emergency Management 2-Weeks Ready Program.

structure, the value of renewable self-consumption will always be less than a net metering tariff that provides full-retail credits.

As a result, with renewable self-consumption, any excess renewable energy stored and used at a later time with battery energy storage would only have a value of about $0.06/kWh to $0.09/kWh. This is a net reduction in savings potential compared to a full retail net metering tariff of about $0.01/kWh. Using an average solar production for Oregon solar installations,[8] this is about **$18/kW-yr of stored solar**.



Value to the Utility

In this study, the Pilot team investigated the grid services defined in the 2019 Pacific Power Integrated Resource Plan (IRP) (energy, operating reserves, transmission and distribution (T&D) upgrade deferral, and generation capacity). The benefit of these grid services to the utility could be achieved through aggregating the BTM battery energy storage resources into a larger kW aggregated unit.

Grid Service	Description
Energy Arbitrage	The practice of purchasing and storing electricity during off-peak times, and then utilizing that stored power during periods when electricity prices are the highest.
Resource Adequacy	A condition in which the region is assured that, in aggregate, utilities or other load serving entities (LSE) have acquired sufficient resources to satisfy forecasted future loads reliably.
Operating Reserves	Demand that the end-use customer makes available to its load-serving entity via contract or agreement for curtailment.
Transmission & Distribution Deferral	Defer or avoid the need for a T&D equipment upgrade that is needed due to demand growth.

To illustrate this impact, the Pilot team chose to investigate what a BTM battery energy storage program could be in 10 years, assuming the same participation rates as the Pacific Power Oregon Blue Sky solar program. The Pilot team chose 10 years as the evaluation period as battery energy storage systems typically have at least a 10-year warranty or performance guarantee. Therefore, the utility can count on grid services benefits from even first year participants for 10 years.

[8] "Oregon Solar Dashboard," Oregon Department of Energy, accessed on December 11, 2020, https://www.oregon.gov/energy/energy-oregon/Pages/Oregon-Solar-Dashboard.aspx.

BTM Program Potential & Participation

Determining Program Potential

As of June 30, 2020, 864 commercial customers were participating in the Oregon Blue Sky program. The Pilot team chose to use 50 kW/200 kWh as an average system size per site as the basis of the calculations.[9] Reserving 50 percent of the storage capacity for resiliency/backup power would leave 100 kWh available for utility use per participant. Using a four-hour duration assumption, the same used in the 2019 IRP, this means there would be up to 25 kW of reliable power capacity for grid services.

For those grid services, which require four hours or less of system availability or operation, the maximum capacity potential is simply the product of the average system's available power capacity and the total count of participants. The result would be about 22 megawatts (MW) (25 kW/participant x 864 participants). While there are potential grid services which can be provided by energy storage which would require more than four hours or even less than a single hour, a four-hour duration was chosen to appropriately apply the annual capacity benefits rates from the 2019 IRP to the potential total participant capacity.

Utility Grid Services Value

The annual participant capacity was calculated assuming it would follow a typical S-curve. An S-curve, or Sigmoidal curve, is an S-shaped curve that predicts how a program might grow over its life cycle. Using the annual capacity benefit rates (see Appendix B, Annual Participation and Value Projection section for further details) and the projected cumulative participant capacity, the total value of grid services over the ten-year period could equal between **$3 million and $20 million**. The table below has the results for each grid service evaluated.

Program Year	Cumulative Participating Capacity (MW)	Energy Arbitrage	Operating Reserves	Transmission and Distribution Deferral	Resource Adequacy	Total
2020	0.1	$3,076	$5,234	$2,290		$10,600
2021	0.4	$12,700	$21,413	$9,368		$43,482
2022	1	$32,803	$54,753	$23,955		$111,511
2023	2.6	$88,244	$145,603	$63,703		$297,550
2024	5.8	$439,875		$145,346		$585,221
2025	10.8	$898,706		$276,815		$1,175,520
2026	15.8	$1,399,507		$414,203		$1,813,710
2027	19	$1,700,560		$509,449		$2,210,009
2028	20.6	$1,873,690		$564,944	$2,207,884	$4,646,518
2029	21.2	$2,064,445		$594,654	$2,238,736	$4,897,835
2030	21.5	$2,284,696		$616,819	$2,190,598	$5,092,113
Total		**$10,798,302**	**$227,003**	**$3,221,546**	**$6,637,217**	**$20,884,068**

Table 1: Utility Grid Service Values

Stacking the Grid Services

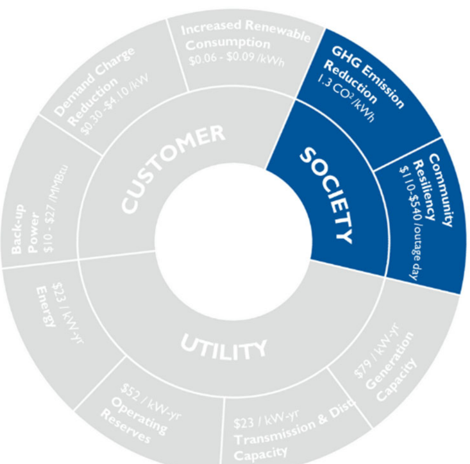
The above table calculates a likely mix of stacked grid service values, assuming the entire battery capacity is available to the utility. In other words, it does not account for stacking these values with customer value streams. Balancing the benefits of battery energy storage requires detailed analysis of both the operational characteristics of the battery and the nature of the value streams it captures. Operating batteries to capture stacked benefits could unlock significantly more value than using batteries to pursue individual value streams in isolation. However, there are often technical and operational

[9] Excluding site #4 due to the preliminary nature of those results.

challenges associated with stacking multiple use cases, and further optimization of these values will uncover the stackable value of each benefit. The extent to which modern energy management systems and software can address these issues is highly variable and dependent on the specific site and application(s).

Grid Service	Service Duration	MW Potential	Likelihood of Stacking
Energy Arbitrage	Hours	22	Low: Requires the system to be able to dynamically adapt to changing pricing.
Resource Adequacy	Hours	22	Moderate: Depends if the system provides firm or peaking capacity.
Operating Reserves	Minutes to hours	22	Moderate: Depends on the type of ancillary service provided.
Transmission & Distribution Deferral	Hours	22	High: Only needs to meet a portion of the peak demand during a select few hours in the year.

Table 2: Grid Services MW Potential



Value to Society

The Pilot targeted critical facilities that would provide emergency services to the surrounding community during a disaster or severe weather. These communities would receive the resiliency benefits of having back-up power at these locations. Additional societal benefits include the reduced GHG emissions associated with the adoption of solar plus storage resiliency systems at critical facilities throughout Oregon.

Community Resiliency

While a catastrophic disaster, such as a major earthquake, may happen once in a system's useful life, severe weather like snowstorms and wildfires tend to occur more frequently in the Pacific Northwest. During a grid outage, the value of having backup power to ensure the availability of the emergency services that these facilities provide can be valued in terms of avoided property damage, injuries, lives lost, and, to a lesser extent, lost revenue.

The Pilot team chose to utilize the Federal Emergency Management Agency's (FEMA) benefit calculator to determine resiliency benefits in high-consequence, low probability events. While the FEMA tool provided a standard valuation approach, valuing resiliency industrywide is still more art than science, and a lot of uncertainty and a lack of comprehensive standards exist for valuing the overall importance of resiliency.

Utilizing the FEMA methodologies, the monetary resiliency benefits to the community are calculated based on the facility type and/or services provided, such as emergency medical services. Factors such as number of people in the community served by the facility, annual incidences per capita (such as fires, crimes, or medical emergencies), the change in response time prior to and during an outage, the difference in any property losses (including costs of housing, missed work, and lost business) prior to and during an outage, and the difference in the value of mortality and injuries prior to and during an outage determine the total value of resiliency that facility provides to the community. The larger the population served, the greater potential of avoided damages, losses, mortalities, and injuries should that facility maintain operations during an outage.

The aggregated community resiliency value was calculated using a similar method as the utility values above. Should battery energy storage resiliency systems be evenly disbursed throughout Pacific Power's Oregon territory, it could be assumed that all of Pacific Power's customers would benefit from these systems. Using this assumption and the total customer count in the FEMA cost-benefit tool for fire stations and shelters, this produced a resiliency value of between about **$600,000 and $3 million** for a single two-week outage that affects all Pacific Power customers. This value does not include fuel savings benefits, which is identified in the backup power customer benefit, but does account for facilities which may or may not have existing backup generation. Further details regarding the methodology for valuing resiliency is provided in Appendix B Valuing Societal Benefits: Community Resiliency section. .

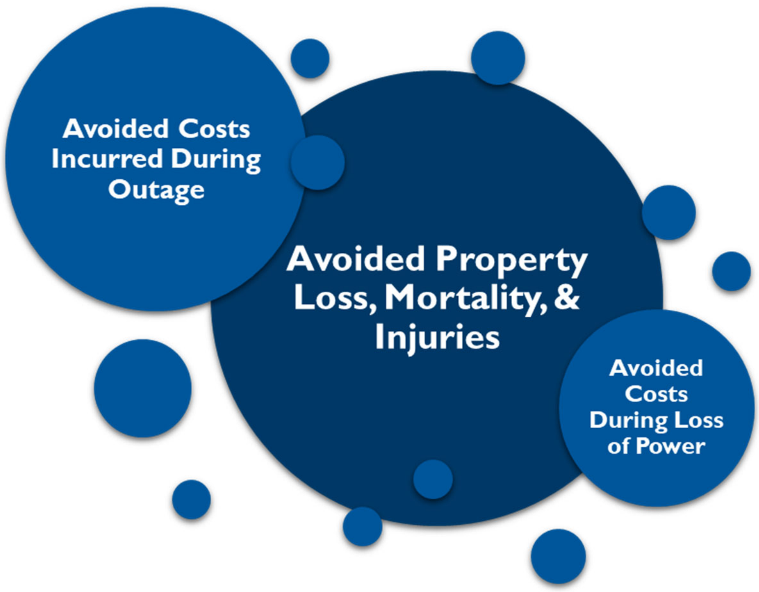


Figure 2: Resiliency Value

GHG Emissions Reductions

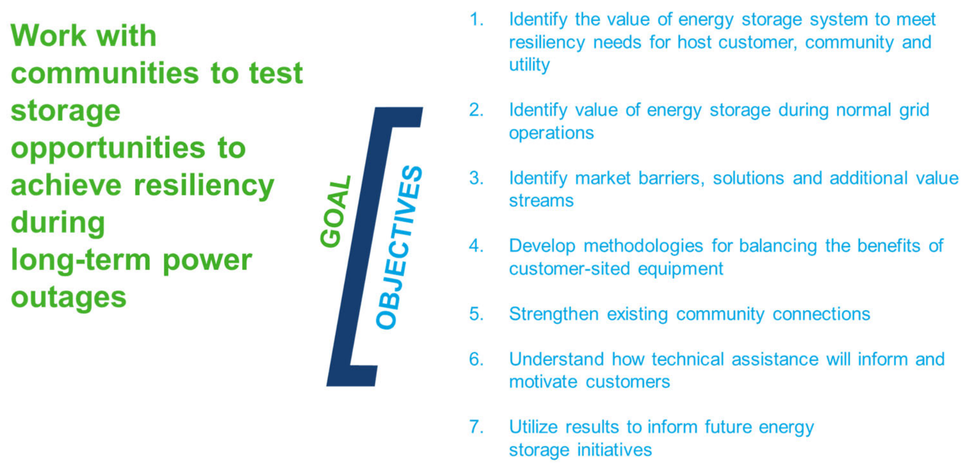
GHG emissions reductions from a solar plus battery energy storage resiliency system come from offsetting utility energy consumption during normal operations and reducing or eliminating fossil fueled backup generator operation during an outage. The average GHG reduction rate of offset utility energy is about 1.3 lbs. CO_2/kWh per site. Comparatively, depending on the fuel, GHG emissions reduction rate was between two and three lbs. CO_2/kWh for all energy consumption during the two-week outage. However, while the average grid emissions rate will decrease over time as the utility puts more renewable generation on the grid, backup generator emissions rates will remain approximately the same. Since there are several variables that can heavily influence the size of a new solar array at any one facility, it is difficult to estimate the GHG emissions reductions associated with a battery energy storage resiliency system during normal operations at this time, so these have not been included in the results. Further, for sites with large existing arrays that can be integrated into a battery energy storage resiliency system, associating GHG emissions reductions from this existing array with the battery energy storage resiliency system would be inappropriate and may be double counting these benefits, which are likely included in another program. However, since GHG emissions reductions during resiliency operations are directly related to avoided fuel consumption from a backup generator, these reductions would not be accounted for elsewhere. Based on a generator with the same output capacity as the average battery energy storage system identified used in the utility value calculations and the avoided emissions rate above, each system would reduce GHG emissions from a backup generator between about 9,000 and 18,000 lbs CO_2 over a two-week outage. This could be extrapolated to a total program potential of between about **3,890 and 7,775 tons CO_2** avoided from a statewide two-week outage.

5. Study Approach

The following section details the methodology for Pacific Power's Community Resiliency Pilot, including the Pilot goals and objectives, and the steps taken to implement the Pilot.

Pilot Goals and Objectives

Pacific Power's goal in offering the Community Resiliency Pilot was to work with critical facilities across Oregon communities to investigate storage opportunities to achieve resiliency during long-term power outages. Over a one-year period, Pacific Power set out to recruit four project sites that would participate in technical storage feasibility studies. In addition to supporting the resiliency needs of critical facilities, Pacific Power sought to consolidate the information gained in the study process into key learnings about BTM battery energy storage that could be used to intelligently shape future program offerings.



Pilot Approach

The Pilot approach started with criteria development to identify and recruit key sites. After recruitment and site selection, the Pilot team began collecting data and scheduling site audits with site participants. A desktop review process provided an opportunity for initial analysis prior to the site audits. This desktop review ensured verification of key inputs into the analysis and enabled a more thoughtful walkthrough with site participants. Upon conclusion of the site audits, the Pilot team completed analysis for each site participant and drafted a final site evaluation report. The Pilot team then shared those site reports with the site participants during a follow-up phone conversation to review the key findings.

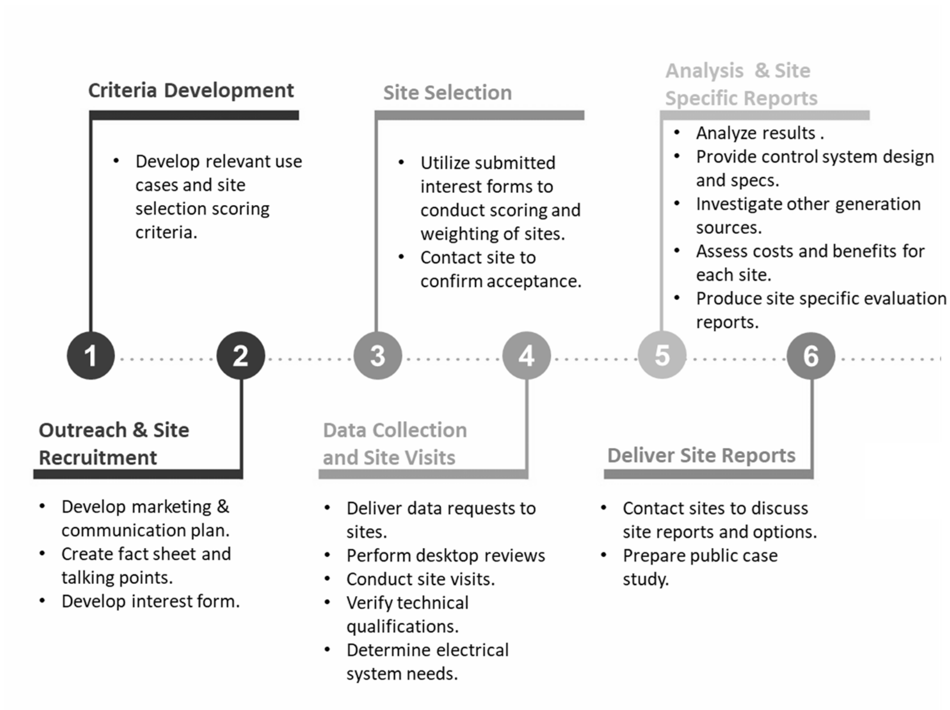


Figure 3: Implementation Steps for the Community Resiliency Pilot

Phase 1: Criteria Development

The Pilot team approached site selection criteria development by overlaying two layers: technical and economic considerations and environmental and social considerations. A key requirement for any facility to participate in the program was that the facility had to have a commitment to serve the community during a disaster event. If the facility was not a central hub or location for disaster response, the facility would not move forward. The below criteria were created to score and weight responses as participants came into the program. A Likert Scale of 1-5 was used for scoring.

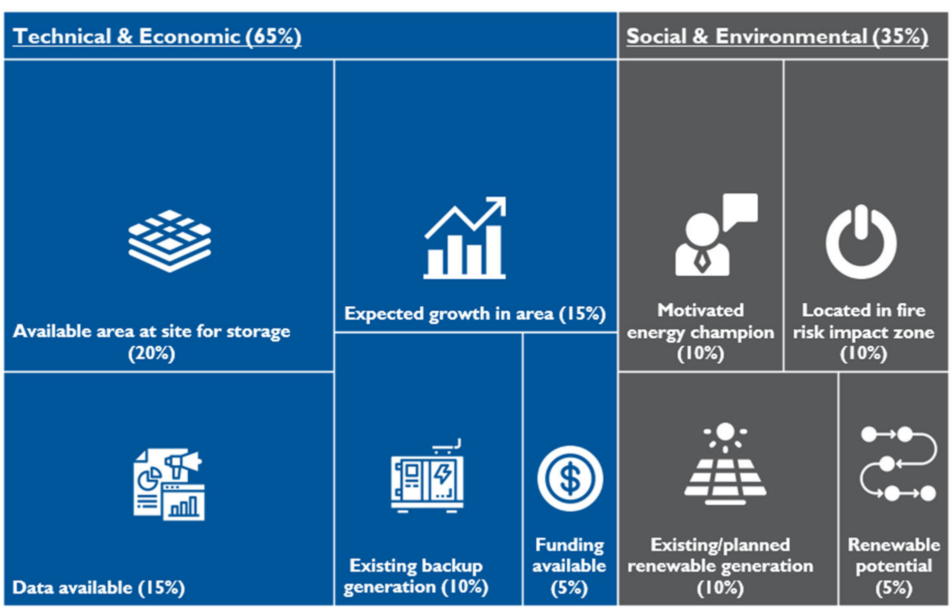


Figure 4: Site Criteria Summary

Phase 2: Outreach and Recruitment

The Pilot team worked with Pacific Power's regional business managers (RBMs) to establish contact with participants and relationships with energy champions in the communities to ensure committed Pilot participation from the start. The Pilot team provided clear communication to participants about the participation steps detailed in 3.

Figure 5: Community Resiliency Pilot Participant Journey

The Pilot team provided RBMs insights into the program overall process. Participants were asked to submit interest forms to ensure movement into the next phase of the program.

Recruitment into the program experienced a number of challenges. COVID-19 created additional delays in getting facilities interested in participating because many of those people involved in disaster planning were called into action with COVID-19 response. Furthermore, a long lead time existed in setting up communication and discussions with the right people. Often, the conversation would pique interest and need to be routed to another individual for follow-up, which highlighted the importance of the consistent involvement of an energy champion able to maintain site engagement.

Phase 3: Site Selection

After potential participants submitted interest forms, the Pilot team scored each interest form for pre-screening. Pre-screening required each site to receive a score above three to ensure that the technical feasibility study would lead to potential implementation. Sites were categorized into types of FEMA-designated critical facilities to understand the landscape of critical facilities within Oregon, and to begin to draw conclusions about storage size and feasibility for each critical facility type.

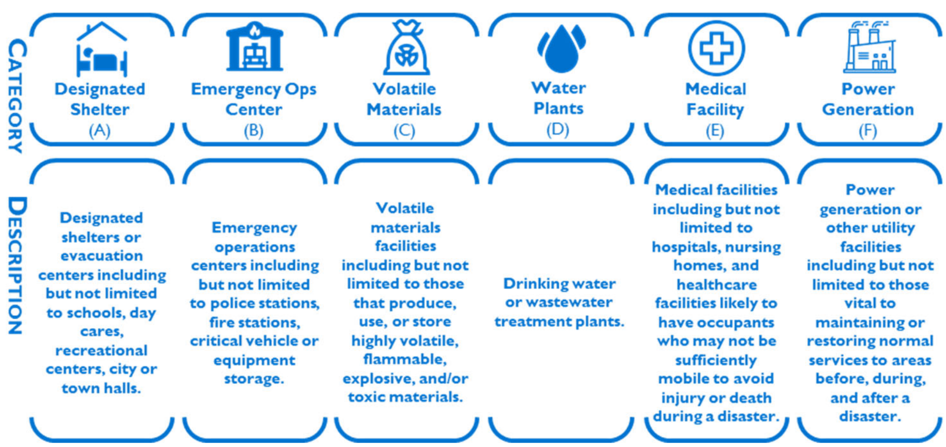


Figure 6: Categorization of Typical Critical Facilities Identified by FEMA

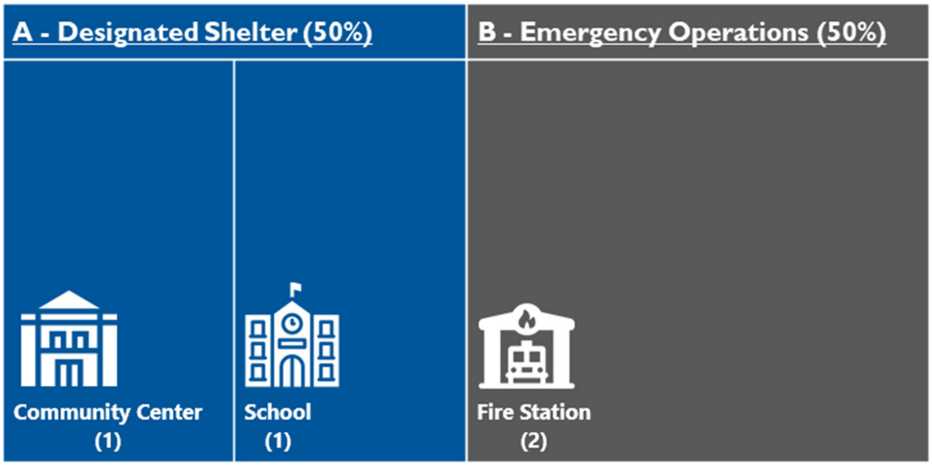
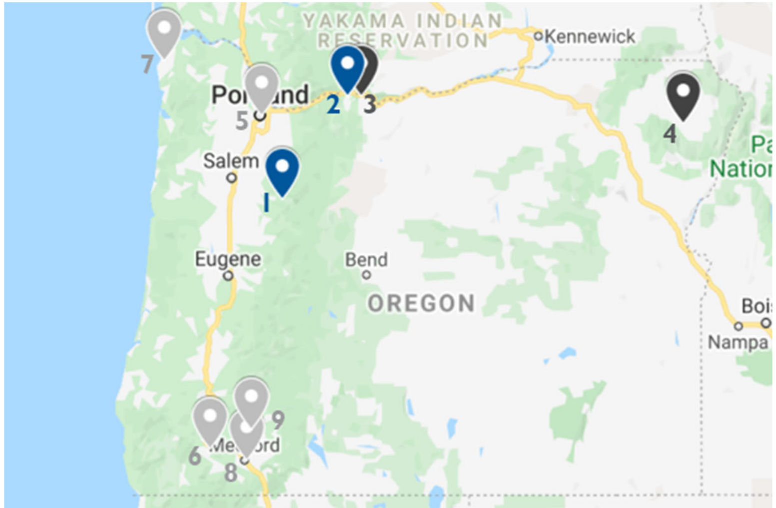


Figure 7: Facility Types of Selected Community Resiliency Pilot Sites

The Pilot team considered and engaged multiple potential sites, eventually narrowing those sites to eight potential sites (see Figure 8 below). Ultimately, the first phase of the Pilot included the selection of four sites across the state. Overall, the Pilot team received the most interest from community shelters and emergency services, categorized in Category A and B.

As shown in Figure 8, the Pilot team identified the following sites for pilot participation. The sites are located across Oregon in areas at risk for various and unique resiliency events.



	Facility Type	FEMA Category
1	Fire Station	B – Emergency Ops.
2	Fire Station	B – Emergency Ops.
3	School	A – Designated Shelter
4	Community Center	A – Designated Shelter
5	Church	A – Designated Shelter
6	Fairgrounds	A – Designated Shelter
7	School	A – Designated Shelter
8	Data Center	B – Emergency Ops.
9	School	A – Designated Shelter

Figure 8: Community Resiliency Pilot Sites

Phase 4: Data Collection and Site Audits

Data Collection

The Pilot team compiled data to determine the suitability of battery energy storage at each of the participating facilities. Some of the data was obtained directly from Pacific Power, while others needed to be provided by Pilot participants (see Appendix D for the data checklist). This included utility usage and general site information such as:

- 12-24 months of utility data
- 12-24 months of third-party supplied utility data (if applicable)
- Building energy management system trend data (if available, for specific end-uses or buildings/areas which might be supported in resiliency event)
- Description of known electrical issues (type of issue and frequency)
- Type of facility, location, square footage
- Typical occupancy schedule
- Building as-built plans/drawings
- Details of any major additions, renovations, demolitions, equipment replacements or upgrades

Utility information for the site was always collected prior to the site audit. Other information was provided either prior to or at the time of the site audit. The most difficult piece of information was building plans/drawings. Most facilities did not have these readily available and locating copies or retrieving them through local permitting jurisdictions was time consuming and often fruitless. However, the information that would have been contained in building plans could be collected through a thorough site audit.

Desktop Reviews

After site selection, and with at least the utility data collected, the Pilot team began the technical analysis by conducting desktop reviews. These reviews involved technical analysis to determine system sizing based on utility usage and assumed or approximated site constraints, such as available space for battery energy storage or generation equipment. The results of the desktop review provide a starting point from which to refine system sizing through additional data collection and/or field verification.

Site Audits (Virtual and In-Person)

The Pilot team provided both in-person site audits and virtual audits to site participants, the latter dictated by COVID-19 protocols as they began to take shape. During site audits, the Pilot team took detailed photos, written notes, and location documentation to capture the existing conditions of the facility as well as the potential for future equipment siting. Virtual audits were conducted through phone and video conference capabilities (collecting the same data as in-person audits), with authorized personnel from the site walking through the facility. The data collected during this process included:

Electrical System and Infrastructure

- Electrical service information (Voltage, phase);
- Switchgear condition/age, capacity, and panels or end-uses served;
- Electrical panels condition/age, capacity, and end-uses served; and
- Transformers condition/age, capacity, and downstream equipment served.

Potential Solar and Battery Storage Equipment Siting

- Any existing photovoltaic (PV) systems or battery storage systems on-site;
- Any existing backup generators currently present;
- Preferred manufacturers, restrictions regarding specific manufacturers
- Solar PV siting preferred locations;
- Approximate available area to locate future solar equipment;
- Available pad mounting locations for battery energy storage system assets; and
- Proximity of potential PV and/or battery energy storage system locations to electrical tie-in(s).

Phase 5: Analysis and Site-Specific Reports

The Pilot team designed the analysis' overall methodology to identify a technically feasible battery energy storage system to provide or supplement the resiliency of a critical facility. This began with a high-level screening that looked at facility attributes, existing and planned resiliency resources, and data availability. After initial screening, the Pilot team collected more detailed facility information and performed a site audit. From there, a trained energy engineer developed baseline conditions and assumptions about the electricity use patterns at the site. This model was used to perform iterative analysis on project configurations. These configurations included existing or new backup generators, existing or new solar PV, and a new battery energy storage system. The result of the analysis is the identification of a system that can provide or reinforce resiliency at a facility.

Key Parameters and Assumptions

- Participating sites are small and medium commercial critical facilities, which are non-networked.
- The Pilot's analysis is manufacturer agnostic and assumes the technology solution to be Li-Ion battery systems.
- Considering these critical facilities' intent for long-term (up to two weeks) operation during emergency and disaster response, the most robust solution would have to be composed of storage, solar and, most likely, a backup (fossil fuel) generator.

Analysis Methodology

Determining Use Cases

The Pilot's main goal was to provide resiliency benefits during disaster events with battery energy storage, so resiliency was the primary use case. However, additional use cases have the potential to provide ongoing benefits outside of resiliency operation, and therefore warranted exploration. Additional benefits from other use cases may increase financial performance of the system without negatively effecting resiliency readiness. The other use cases that were evaluated were demand charge management and increased solar PV self-consumption.

- **Demand Charge Management.** Since these are commercial customers, their utility tariffs have demand charges associated with them, so this would allow customers to use a portion of the battery energy storage system to shave their peak demand use and realize monthly bill savings.
- **Increased Solar Self-consumption.** Considering these resiliency systems are intended to support facilities for up to a two-week outage, it would be difficult to size a battery energy storage system large enough to achieve that goal without the integration of any generation resources. However, the addition of conventional and renewable generation may allow a facility to achieve this goal. Therefore, utilizing existing or new renewable generation such as solar PV for resiliency permits the customer to realize the benefits from that solar outside of the resiliency context. With battery energy storage, excess solar generation can be stored and then used overnight, rather than sending it back onto the grid.

The Pilot team considered customer use cases including TOU charge management and demand response, but determined that, under current tariffs and program offerings, these use cases are not applicable at this time. However, there might be future opportunities for these use cases.

Analysis Process

The analytical process started with a data request and a brief screening questionnaire. This data and information allowed analysts to develop annual gross load profiles, determine baseline utility costs, estimate site conditions and constraints, and determine an outage load profile.

- **Baseline Load Profiles.** Using utility meter data and preliminary information provided by the site, the Pilot team developed baseline load profiles of current electricity use and bill costs as well as initial system sizing and feasibility.

- **Critical Load Analysis.** The audit team reviewed building drawings and equipment inventories collected from the site audit of each facility for battery energy storage and other distributed energy resources. With this information and input from site representatives, the team identified those building loads and electrical circuits which would need to remain powered during an outage. The electrical specifications of the equipment and capacity of the circuits identified then determined the critical load(s) of the facility.

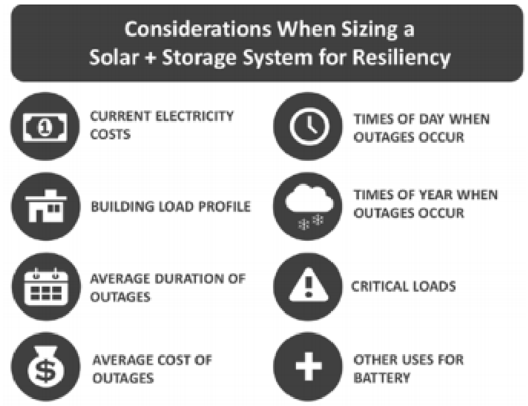


Figure 9: Considerations When Sizing a Solar and Storage System for Resiliency (National Renewable Energy Laboratory 2018)

- **Resiliency Scenarios.** There were three configurations that could provide resiliency power to the facilities—(1) the conventional configuration that includes just a backup generator (typically diesel fueled), (2) an enhanced configuration that includes an energy storage system in addition to the backup generator, and (3) a comprehensive configuration that includes solar and energy storage in addition to the backup generator. Each configuration was evaluated for the potential to reduce GHG emissions, provide electricity bill savings, lower the risk associated with generator fuel deliveries, and provide community resiliency benefits. A more detailed description of this analysis and evaluation of these configurations is in the Section 5: Technical Investigation of Storage.
- **Battery Energy Storage System Sizing Analysis.** The Pilot team evaluated the critical facilities for battery energy storage and other distributed energy resource capabilities. An in-depth analysis investigated battery energy storage configurations, with and without PV, determined daily discharge and charge cycles, and considered any physical or technological site constraints and examined applicable use cases. During this step in the process, the Pilot team determined a potential operation schedule and sizing of the battery energy storage system.
- **Benefits and Costs Analysis.** Finally, the Pilot team assessed the potential costs and benefits of battery energy storage and performed an economic analysis for each site. For the resiliency valuation, the team used the cost benefit analysis procedure developed by the Federal Emergency Management Agency (FEMA 2011). This procedure quantifies the costs of a facility being unavailable during a critical disaster time, essentially identifying the costs avoided by keeping the facility up and running, or, framed slightly differently, the benefits having the facility available to perform its critical functions during a disaster. The FEMA procedure is different depending on the type of facility being considered.

Analysis Tools

The Pilot team used a combination of industry standard software and proprietary calculators and tools developed specifically for this Pilot in the analysis and evaluation.

- **HOMER Grid.** HOMER Grid combines engineering and economics information in one comprehensive model. It rapidly performs complex calculations to compare multiple components and design outcomes, identifies points at which different technologies become cost-competitive, and considers various options for minimizing project risk and reducing energy expenditures. The HOMER software was used to determine project costs and utility bill costs and savings.
- **Energy Balance Tool.** TRC's energy balance tool uses hourly interval load profiles and synthetic distributed energy resource performance profiles to determine an adequate resource mix to deliver power to facility loads during an outage. This tool was used to confirm system configurations that could provide enough power to the site loads at all hours during an outage.
- **FEMA Cost Benefit Analysis Calculator.** The FEMA Cost Benefit Analysis (CBA) calculator was developed based on the model used to assist the New York State Energy Research and Development Authority with the evaluation of the economic viability of microgrids. It was developed to estimate the costs and benefits of a microgrid from the perspective of society as a whole, taking into account the benefits of maintaining operations at the facilities served by the microgrid in the event of a prolonged emergency. This calculator was used to produce a resiliency value for each system configuration at each site.
- **Interruption Cost Estimate (ICE) Calculator.** The ICE Calculator is a tool designed for electric reliability planners at utilities, government organizations, or other entities that are interested in estimating interruption costs and/or the benefits associated with reliability improvements. This calculator was used in combination with the FEMA CBA calculator for emergency shelter facilities.

Phase 6: Site Evaluation Reports and Discussions

The Pilot team assembled site evaluation reports for each site participant. These reports encompassed key areas of interest to the site including the resiliency scenarios analyzed, costs and benefits of the battery energy storage system, key considerations for technical implementation, and recommendations on potential other grants and funding available to the site to leverage to support implementation.

Follow-up conversations were scheduled with the sites after these reports were delivered to discuss the site reports and key findings.[10]

6. Site Specific Storage Feasibility

The Pilot explored the technical feasibility of BTM battery energy storage for commercial customers through data analysis and site audits, ultimately resulting in site evaluation reports for the customer. This included investigation into key components that would help provide information to customers to determine financial and technical feasibility to implement storage at their facilities.

Exploring technical feasibility of each site included the following steps:

- **Step 1: Developing resiliency scenarios.** Scenarios were developed from standard (conventional fossil fuel backup generation) to comprehensive (maximizing solar plus storage) to show the varying degrees of resiliency that a customer could achieve.

[10] The results of each site evaluation are published in Appendix E of this Report.

- **Step 2: Undergoing critical load identification**. As discussed previously, critical load identification occurred for each site to understand the critical loads that would be required to run during a disaster event.
- **Step 3: Sizing the battery systems.** The Pilot team considered how to properly size the battery storage systems, taking into account existing back-up generation and solar potential.
- **Step 4: Determining interconnection considerations.** The Pilot team evaluated interconnection considerations to determine whether any barriers exist in bringing a new resource onto the utility grid.
- **Step 5: Uncovering costs of the systems.** Costs explored included capital, operation, and maintenance for both existing backup generation, storage, and solar systems.
- **Step 6: Revealing overall technical feasibility for the storage sites.** The feasibility evaluation analyzed how well a battery energy storage system could provide the following services/benefits to the site: (1) ability to provide backup power generation and community resiliency, (2) ability to reduce carbon footprint, and (3) ability to reduce energy costs.

Step 1: Resiliency Scenario Development

The technical feasibility studies analyzed three resiliency system options/scenarios. The **Standard** resiliency system included only a backup generator, which is the conventional option. This provided a baseline against which to compare resiliency systems with battery energy storage and solar. The **Enhanced** resiliency system would add battery energy storage to allow the facility to operate up for to two days without the need to run the backup generator. When the battery energy storage system was depleted, the backup generator would supply power to the facility and charge the battery energy storage with the excess capacity. The **Comprehensive** system would build on the **Enhanced** system by adding solar generation to the backup generator and battery energy storage to extend the amount of time the facility could operate without the backup generator. As the system options progress from **Standard** to **Comprehensive**, the potential for GHG emissions reductions, electricity bill savings, and lowering risk associated with generator fuel deliveries improves.

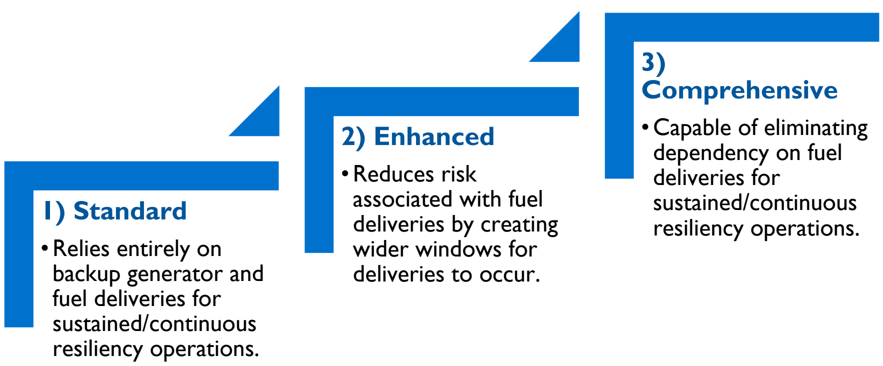


Figure 10: Resiliency System Scenarios Analyzed

1. Standard Resiliency: Utilize existing backup generation

The first step in the technical analysis was to determine the baseline resiliency operation, which involved the operation of any existing backup generation for the entire two weeks. If the facility already had a generator, no additional sizing or costs was needed. Generator specifications (e.g. fuel curve, power output, etc.) were input to the energy modeling software, which determined the total fuel consumption and cost.

Using only a backup generator over a longer-term outage has an inherent risk associated with it. Generators pose the risk of being unavailable due to problems with maintenance, failing to start and support load, and failing to run for the duration of the outage. Fuel-related risks are highest for widespread, long outages. When the generator is working properly but stalls due to insufficient fuel, a failure of fuel supply (FFS) occurs. FFS for a generator generally occurs when resupply shipments are disrupted, and the generator exhausts its fuel tank. Under normal conditions, fuel can be replenished well before a generator exhausts its fuel tank. However, long outages often coincide with abnormal conditions, such as extreme weather events or disasters, which can close roads and impede normal transportation. Despite common assertions regarding the ability, or inability, to resupply generators during natural disasters, very little analysis has been conducted and no specific data set was identified with information on the likelihood of resupply during long outages. For this analysis, the Pilot team assumed a 14 percent likelihood of a failure of resupply based on NREL's "A Comparison of Fuel Choice for Backup Generators".

2. Enhanced Resiliency: Utilize existing backup generation and add new battery energy storage system

The next step involved determining the battery energy storage system size that would be capable of adequately charging from the generator and discharging to meet site demands and reduce the risk associated with fuel resupply. Reducing fuel resupply risk comes from more efficient generator operation (running the generator at full load) and decreasing generator run time frequency. The storage inverter has to have the same capacity (kW) as the backup generator for two reasons: (1) it has to be capable of picking up the surge and steady-state current demands of the site, and (2) it has to be able to charge from the net capacity of the generator.

3. Comprehensive Resiliency: Upgrade and optimize backup generation and add new battery energy storage system and new solar

After the initial storage sizing was determined, the analysis added solar PV arrays through an iterative process up to the physical limit at the site. Solar would further reduce risk associated with fuel resupply by further lessening the generator run time frequency. This increases the window of time between which fuel deliveries can be made.

Step 2: Critical Load Identification

Some of the sites that were analyzed had existing backup generation and/or electrical infrastructure to accommodate a portable backup generator. While these sites had already identified which loads may be considered critical, the costs and benefits of either further subdividing those loads to potentially have a smaller battery energy storage system size or sizing the battery energy storage to carry the loads already behind the backup generator were considered.

Two of the sites had equipment and electrical configurations, which would allow the entire facility to automatically or manually switch power to a backup generation source. A third site had a small set of critical loads isolated behind a subpanel, which would automatically switch to a backup generation source in the event of an outage. Typical end-uses that were identified as critical loads included:

- Indoor lighting
- Electric unit heaters
- Ventilation fans
- Apparatus door motors
- Electric kitchen appliances
- Mini-split heat pump or air conditioning units
- Electrical outlets and receptacles

The sites with full facility backup configurations had connected loads totaling about 100 kVA. The partial facility backup configurations had about 20 kilovolt amps (kVA) of connected load.

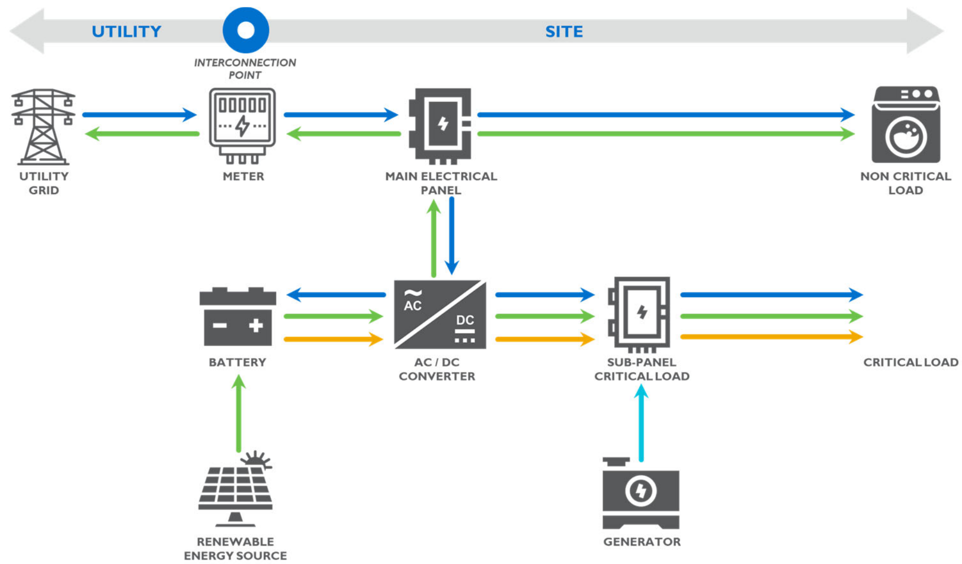


Figure 11: Typical Critical Load Scenario

Step 3: Sizing the Battery

The primary goal of this evaluation was to determine a battery energy storage system size that would reduce or eliminate the need to operate a backup generator during a two-week outage. However, the size of such a battery energy storage system which could provide the entirety of backup power for two-weeks would likely be difficult to locate at the site as well as be overwhelmingly cost prohibitive. Therefore, evaluating a system size which might provide some stand-alone short-term resiliency, and which might also be charged with onsite generation (whether renewable or backup) for longer outages could meet this main goal. The battery energy storage system size which might provide that balance could provide up to two days of resiliency operation without a backup generator or renewable energy source. Secondary sizing considerations were based on any additional power or battery energy storage capacity needed to reduce electricity costs and potentially increase project viability.

Facility Type	Total Battery Energy Storage Capacity (kWh)
Fire Station	**475**
Shelter	**830**
Community Center	330
School	500
Total	**1,305**

Figure 12: Sites Battery energy storage Capacity Needs

Pairing the Battery with Renewables

In order to reduce or eliminate the need to operate a backup generator during a two-week outage, it would be necessary for the battery energy storage system to utilize new solar generation, either developed on its own, or to integrate with any existing solar generation resources at the facility. Most sites have at least a small amount of solar potential available that could be utilized in a resiliency system. A significant amount of solar (utilizing all available space at the site), new or existing, would be required to minimize backup generator operation and fuel consumption, as illustrated in figure 15. One site has a significant existing solar array that could be used.

Facility Type	Total Solar AC Capacity (kW)
Fire Station	**74**
Shelter	**104**
Community Center	38
School	65
Total	**178**

Figure 13: Sites Total Solar AC Capacity

Determining Total Backup Generator Capacity

Proper sizing of a backup power system is crucial to the success of any installation and requires a good working knowledge of electricity and its characteristics, as well as the varying requirements of the electrical equipment comprising the load.

- When analyzing the electrical load, the Pilot team consulted the manufacturer's nameplate on each major appliance or piece of equipment to determine its starting and running requirements in terms of watts, amps and voltage.
- When choosing the generator output for commercial applications, the Pilot team selected a rating approximately 20 – 25 percent higher than the facility's peak load (for example, if the load is about 40 kilowatts, the Pilot team selected a 50 kW genset). A higher rated system will operate comfortably at approximately 80 percent of its full capacity and provide a margin of flexibility should the load increase in the future.

It is important to understand generator sizing in order to account for the load it will need to handle. Electric motors are particularly difficult for backup power systems because starting an electric motor requires two to three times its nameplate amperage or wattage. Surge current is the result of an increased current demand by the motor in order to get to its steady-state level. Figure 14, below, shares details regarding the total battery energy storage capacity needs of the sites.

Facility Type	Total Backup Generator Capacity (kW)
Fire Station	**96**
Shelter	**175**
Community Center	75
School	100
Total	**271**

Figure 14: Total Backup Generator Capacity

Step 4: Interconnection Considerations

Pacific Power supports the implementation of battery energy storage resources and is currently developing a policy for battery interconnections. In the interim, the following technical requirements apply to battery system interconnection requests to ensure safe and reliable operation of the energy grid. These requirements may change as Pacific Power continues to develop its battery interconnection policy.

- Battery systems shall not export power through the point-of-interconnection to the energy grid.
- Battery inverters/converters shall be IEEE 1547 & UL 1741 Certified, with intentional islanding permitted.
- Battery systems shall comply with applicable electrical codes.
- A one-line drawing shall be required with each battery system interconnection request.
- An AC disconnect switch shall be required for every battery system.
- A transfer switch shall be required with every battery system.
- All inspections provided by the authority having jurisdiction must clearly reflect inspection of the battery system.

Step 5: Capital and Operation and Maintenance Costs

Any islandable solar and battery energy storage system requires additional expenses above the cost of a non-islandable system. These added costs depend on many factors and include additional hardware components such as transfer switches and critical load panels; software components; and electrical design, permitting, and safety considerations. In addition to new equipment for islandable capabilities, rewiring existing equipment and/or infrastructure must also be included. The costs to island can be highly variable and depend on a multitude of site-specific factors. Based on anecdotal experience, the cost to island a system might add incremental expenses ranging from 10 – 50 percent of the non-islandable solar and battery energy storage system cost.[11] The Pilot sites evaluated already had backup generators and/or existing hardware components to provide automatic or manual transfer to a backup power supply. Therefore, the cost of resiliency was relatively minimal. The following sections identify the typical costs for non-islandable Li-Ion battery energy storage and solar equipment.

Battery Energy Storage Capital Costs

Costs for battery energy storage systems were determined using California's Self-Generation Incentive Program's[12] (SGIP) publicly available data. Since the main portion of the system is the storage medium, battery energy storage costs are typically identified on a per watt-hour (Wh) basis. Similar to solar, battery energy storage system installation costs decrease with larger system sizes, as there are some efficiencies and economies of scale that come into play. The following table identifies the system costs used in the analyses of each site.

[11] Joyce A. McLaren, Seth Mullendore, Nicholas D. Laws, and Katherine H. Anderson, "Valuing the Resilience Provided by Solar and Battery Energy Storage Systems," National Renewable Energy Laboratory, February 5, 2018, https://www.nrel.gov/docs/fy18osti/70679.pdf.

[12] California SGIP Weekly Statewide Reports, accessed June 15, 2020, https://www.selfgenca.com/documents/reports/statewide_projects.

Battery energy storage Cost per Watt-hour (2020 USD/Wh)[13]	
System Size (Wh)	**Cost**
5,000	$1.14
10,000	$1.11
100,000	$1.02
200,000	$0.99
500,000	$0.96
1,000,000	$0.93
>1,000,000	$0.91

Figure 15: Storage cost Per Watt

Battery Energy Storage Operation and Maintenance Costs

Battery energy storage systems have requirements for periodic maintenance and are typically identified by battery energy storage system provider. Regular maintenance activities are minimal, but can include basic cleaning of the system enclosure, modules and other components inspection for corrosion, regular capacity testing, and with larger systems, ventilation filter changing. The first year fixed operations and maintenance (O&M) costs used in the analysis for any battery energy storage system proposed at a facility was $10.40/kW per year. Variable O&M, based typically on the watt-hour throughput of the system, was negligible given the application. Most Li-Ion battery energy storage system providers or manufacturers offer warranties that cover typical operation and use cycles. These are usually at least 10 years in length and cover the system components and installation.

Solar Capital Costs

Solar costs were based on research literature benchmarking costs of residential, commercial, and utility-scale PV systems built in Q1 2018 nationally. These costs then were adjusted for inflation to generate the **new array** costs in the table below. Since some of the facilities had existing solar, costs for reconfiguring the arrays for a resiliency application were also developed. The table below has the *rewired arrays* system costs, which only include those labor and equipment components associated with the reconfiguration.

[13] Based on SGIP real-time public report as of June 15, 2020, https://www.selfgenca.com/report/public/.

Cost per Watt-DC (2020 USD/Wdc)[14]		
System Size (W)	New Arrays	Rewired Arrays
6,200	2.53	1.39
100,000	1.90	1.32
200,000	1.76	1.20
500,000	1.60	1.06
1,000,000	1.49	0.98

Figure 16: Solar Cost Per Watt

Solar Operation and Maintenance Costs

O&M costs include preventative maintenance, scheduled at regular intervals with costs typically increasing at an inflationary rate, as well as corrective maintenance to replace components. The first year O&M costs used in the analysis for any new solar array proposed at a facility was $16.60/kWdc per year. PV modules typically have manufacturer warranties of 25 to 30 years, and inverters typically have 10 to 15-year manufacturer warranties.

Step 6: Overall Feasibility

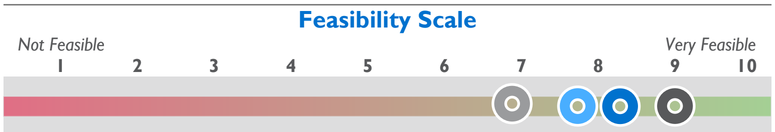
The feasibility evaluation analyzed how well a battery energy storage system could provide the following services and benefits to the site: (1) the ability to provide backup power generation to the facility and support community resiliency, (2) the ability to reduce they facility's carbon footprint, and (3) the ability to reduce the facility's energy costs.

The financial assessment utilized current utility tariff structures and equipment and technology pricing. While a battery energy storage system may be limited in providing some of these services and benefits under present conditions, in general, utility tariffs are moving towards more dynamic rates, and the battery energy storage industry continues to mature—both factors that likely to increase the value of an battery energy storage system in the future.

Backup Power Generation and Community Resiliency

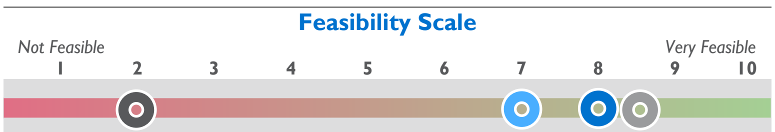
A comprehensive resiliency system (*i.e.*, storage and additional solar) is a technically viable solution to provide long term resiliency with minimal to no dependency on fossil fuels. The battery energy storage and solar components of the system would reduce the fuel usage and run time of any backup generation and primarily use it to charge the battery energy storage during an extended outage. Three of the four sites had existing backup generators or plans for backup generation already on site (the fourth does not appear to have a backup generator, but that has yet to be confirmed with the site). Having backup generation and associated equipment already at the facility increases community resiliency viability. Scores for each site is in the graphic below.

[14] Ran Fu, David Feldman, and Robert Margolis, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018," National Renewable Energy Laboratory, November 2018.



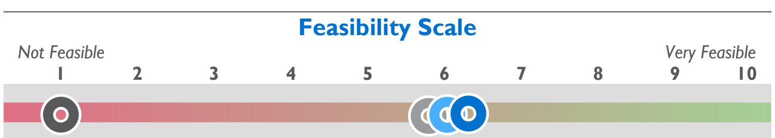
Reduced Carbon Footprint

The construction of new solar arrays has the potential to eliminate nearly all GHG emissions related to grid electricity consumption *and* reduce emissions associated with backup generation when used in an outage. Sites are typically limited by available space for solar, so this was the most common limiting factor in achieving greater GHG emissions reductions. The following graphic illustrates how each site faired in its potential to achieve GHG reductions.



Reduced Energy Costs

There are significant utility bill savings associated with the comprehensive system option. These savings are primarily attributed to net energy metering benefits associated with the construction of new solar arrays. While using the battery energy storage component of the system may not reduce energy costs, battery energy storage allows the facility to adapt and take advantage of any future opportunities presented by changes to utility rate structures the regulatory environment. Sites that had space to host new solar arrays scored higher than those that could not. The graphic below illustrates the energy cost reduction potential of each site.



7. Pacific Northwest Storage Vendor Overview

To understand in greater detail the BTM battery energy storage market in the Pacific Northwest, the Pilot team reached out to various actors that provide BTM services to understand the opportunities and barriers to offering storage to commercial customers in Oregon. The Pilot team designed questions to reveal each vendor's experience with commercial-scale battery energy storage, their current product and service offerings, and each vendor's perceptions of the Oregon commercial storage market at-large.

Vendor Background

The Pilot team identified vendors through multiple channels, including web-based research, multiple referrals from the Oregon Solar Energy Industries Association, and leads gathered from vendor interviews. The Pilot team reached out to 12 vendors total, including 10 solar developers who also install battery energy storage.

The Pilot team secured conversations with four vendors. The vendors identified are based in Oregon, Washington, California, and Texas. Two of the four vendors install Tesla batteries exclusively and do not employ third-party equipment for metering and monitoring purposes. One vendor is known as a BTM storage aggregator, and they leverage multiple third-party devices in their storage projects to maximize the desired grid services of the project. The fourth vendor partners with multiple non-manufacturer storage aggregators to implement their California projects.

Vendor Type	Count	Interviews Conducted	Works in Oregon
Solar/Storage Developer	10	3	3
Storage Aggregator	1	1	0
Manufacturer	1	0	0

Figure 17: Vendor Overview

All vendors are familiar with the Oregon commercial battery storage market, either through direct experience working in the state or by monitoring various economic indicators of the state's market. Three of the four vendors have been operating in the Oregon market for at least 10 years. The largest vendor interviewed has not developed a project in Oregon to-date. The vendors who have experience in the Oregon market said that they have installed fewer commercial storage projects than they would like, due to low demand. Two of the three vendors operating in Oregon said they had installed just two commercial storage projects to date, and the third vendor operating in Oregon reported zero commercial storage projects to date.

Vendor Key Findings

The findings listed below are highlighted for two reasons: (1) their relative frequency of mention during interviews, and (2) the significance they were assigned by vendors during the interview.

- There is no financial case for commercial customers to invest in storage in the current Oregon market.
- Utility incentives are a crucial driver of commercial battery energy storage projects.
- Value stacking is counterproductive in storage projects designed for energy resiliency.
- Pacific Power and Portland General Electric opt-in TOU programs do not incentivize the development of storage projects due to the small delta between peak and off-peak rates.
- There is a missing range (100-500 kWh) in the size of commercial-scale batteries available to the current market.

Most vendor responses related to the key findings are informed by real experience operating in Oregon for at least a decade. Vendors indicated that a commercial battery energy storage market is struggling to exist in the state, and there are multiple contributing factors.

Differences Between California and Oregon

The California storage market was often alluded to as an example of a robust market with significant activity and demand. When compared to California, Oregon lacks three crucial drivers of commercial storage development. Those drivers include:

- Substantial utility incentives for commercial storage systems;
- Relatively high demand charge levied by utilities; and

- A substantial delta between peak and off-peak rates.

All vendors stated that substantial utility incentives are necessary if Oregon wants to see greater demand for commercial-scale storage, regardless of whether projects are driven by resiliency or other customer needs. Without enough incentives available, the business case for commercial clients quickly falls flat when the developer quotes the first cost of the battery. When asked about the value utility incentives can provide to storage projects, one vendor responded, "Incentives are everything for a commercial client."

Uniqueness of Resiliency

Multiple vendors made the point that resiliency projects are unique in nature. Variability in demand needs among sites, coupled with site constraints, makes resiliency projects more expensive on average. The increased cost that comes with resiliency projects when compared to systems that provide other grid services makes it more difficult for a developer to communicate a return on investment that makes business sense to the customer. Without a subsidy for these projects, a customer's personal value for disaster resiliency and their existing assets as a company and as an individual become the sole drivers of a commercial storage market.

One vendor expanded on what makes resiliency projects unique. Stacking values within a system designed for energy resiliency inhibits the functionality of all additional services built into the project. This vendor employs artificial intelligence programming within its systems to predict the likelihood that the battery's stored power will be needed, adjusting the ratio of available power accordingly. However, the vendor admits that no predictive software is perfect.

Cost of Power and Energy

Two of the vendors interviewed explicitly cited Oregon's relatively low commercial demand charges and the small delta between on-peak and off-peak TOU rates.

Without the need to mitigate high demand charges or large deltas in TOU rates, resiliency appears to be the primary motivator for Oregon customers. Oregon vendors shared that disaster resiliency and the mitigation of non-emergency outages are the primary motivators for their customers, the vast majority of whom are residential. Vendors TRC spoke with do not believe the current environment in Oregon is conducive to the noteworthy adoption of commercial storage.

Missing Battery Sizes

According to vendors, another barrier to a ripe commercial market is a missing range in available product sizes. All four vendors mentioned the lack of product options available to them—systems classified as "*small commercial, three-phase*" storage (i.e. 100-500 kWh). One vendor cited the greatest need exists within a narrower range of capacity from 100-200 kWh in size. Many commercial clients need a system that falls somewhere in between to cover their critical loads, and when there is not one available, the return on investment does not pencil out for what is available to them.

Vendor Overview Conclusion

The vendor investigation revealed that the Oregon market for commercial-scale storage is in its infancy. Structural factors including incentives and commercial electricity rates are delaying growth in the Oregon market according to vendors. In addition, vendors operating in Oregon do not have access to battery energy storage systems appropriately sized for many of their clients' needs. Multiple vendors want to participate in discussions that could help utilities design long-term solutions that advance the adoption of storage in commercial settings, whether customers are searching for energy resiliency or other benefits battery energy storage can offer.

8. Lessons Learned

Over the last year, the Community Resiliency Pilot has uncovered key lessons learned revealing steps that may be taken to create a successful BTM battery energy storage program for Pacific Power customers.

The lessons identified below highlight the key considerations that could ensure greater monetization of grid services, create greater resiliency benefits, and ensure installation of storage systems.

Tie technical assistance to funding opportunities to ensure follow-through and adoption of technical recommendations.

- Technical studies on their own are helpful, but without incentive dollars to support adoption (capital costs support, monthly capacity payments to customers, or beneficial tariff design), the Pilot suffered lower than expected participation rate and follow-through from initial conversations with many potential program participants.
- Demand charge reduction and TOU rates were not currently significant enough to monetize other benefits of storage, ultimately resulting in a harder business case to sell to the facility.

Expand the Community Resiliency Pilot to a broader program to unlock societal and utility benefits.

- Communities can achieve resiliency benefits through the thoughtful deployment of battery energy storage systems. Battery energy storage provides a more resilient back-up system then a standard back-up generator by reducing dependency on fuel deliveries and infrastructure corridors that provide relief services during disaster events.
- The Pilot teams anticipates between $3 million to $31 million dollars of potential grid services benefits that could accrue with the expansion of this Pilot into a full-scale program.
- The community benefits of a comprehensive resiliency program could be in the range of $1.6 million to $9 million over the next 10 years.

Adopt effective policies, systems and processes to enable greater resiliency value and enable all the benefits of battery energy storage.

- Commercial facilities' adoption rates of battery energy storage systems in Oregon remain low, in part because the economics of battery energy storage are not competitive with the alternatives. Appropriately designed policy mechanisms including incentives, grant funding programs, and rate design can encourage adoption and promote widespread resiliency benefits throughout Oregon
- Vendor interviews uncovered a great need in the Pacific Northwest for incentive or grant dollars to kick-start the storage market for commercial and residential customers in Oregon. Successful policies will provide the industry with market certainty.
- Pacific Power needs to develop the capability to effectively manage battery energy storage resources in order to harness and leverage the associated grid services benefits.
- The benefit stack for storage is limited when only investigating one facility; greater resiliency benefits can be achieved more cost-effectively by expanding the view to the community through

a cluster of critical facilities. The benefits of this microgrid concept would require further development of policies and systems.

Carefully consider the outage duration that a battery energy storage system is being designed to address.

- The Pilot team adhered to Oregon's Office of Emergency Management 2-Weeks Ready timeframe in evaluating the technical requirements of battery energy storage systems. This timeframe was developed in the context of the resources necessary to respond to earthquake and tsunami events expected in the Pacific Northwest. This two-week timeframe provided a standard length to consider, but it resulted in dependency on backup generators.
- Shorter anticipated grid events will reduce storage system costs as well reduce reliance on backup generators creating a better business case for investment.
- Existing commercial sites had limited space to add and expand new or additional solar, resulting in a higher reliance on operating the existing backup power generators due to the length of the outage time.

Continue to conduct virtual site audits when possible to alleviate unnecessary visit costs and keep customers safe.

- While a desktop review can provide the starting point for a technical requirements of a battery energy storage system, a walkthrough of the site is valuable in identifying key site constraints and considerations to inform refinements to those technical requirements.
- Most small and medium-sized commercial facilities do not have complex mechanical or electrical equipment, which permits engineers and technical staff to perform a virtual site visit hosted by a site representative. With the guidance of technical staff, the site representative does not need to have extensive knowledge, training, or certifications to identify specific areas and equipment that might be impacted by a new energy storage system.
- Battery energy storage sizing and analysis does not require the extensive inventory and end-use analysis as is typically included in a level 2 energy audit, so the audit can be more targeted to specific spaces and equipment that would be used during an outage.
- Using initial intake forms that provide the basic information and high-level data, virtual auditors can create a more specific walkthrough plan. With this preliminary information, a virtual walkthrough can be performed efficiently, with a focus on confirming certain details of the site.

9. Appendix A: Grid Services Definitions

Pilot Stakeholders	Grid Service	Definition
Customer[15]	Demand Charge Reduction	Demand charge is the electricity cost based on the highest demand interval. Reducing peak demand reduces the demand charge.
	Back-up Generation	In the event of grid failure, battery energy storage paired with a local generator can provide backup power at multiple scales, ranging from second-to-second power quality maintenance for industrial operation to daily backup for customers.
	Increased Renewable Self-Consumption	Minimizing export of electricity generated by BTM PV systems to maximize the financial benefit of solar PV in areas with utility rate structures that are unfavorable to distributed PV (e.g., non-export tariffs).
Utility[16]	Energy	The practice of purchasing and storing electricity during off-peak times, and then utilizing that stored power during periods when electricity prices are the highest.
	Operating Reserves[17]	Demand that the end-use customer makes available to its load-serving entity via contract or agreement for curtailment.
	Transmission and Distribution Capacity[18]	Defer or avoid the need for a T&D equipment upgrade that is needed due to demand growth.
	Generation Capacity[19]	A condition in which the region is assured that, in aggregate, utilities or other LSE have acquired sufficient resources to satisfy forecasted future loads reliably.
Society	Community Resiliency[20]	Defines resiliency as an energy system's ability to withstand "*high-consequence, low-probability*" events and to regain normal operational activity after such events occur
	Greenhouse Gas Emission Reduction[21]	Decrease of gases that are trap heat in the atmosphere are called greenhouse gases including carbon dioxide, methane, nitrous oxide and fluorinated gases.

15 Garrett FItzgerald, James Mandel, Jesse Morris, and Hervé Touati, "The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid" Rocky Mountain Institute, September 2015, http://www.rmi.org/electricity_battery_value.
16 Terms mimic PacifiCorp 2019 Integrated Resource Plan, Volume II, Appendices M-R, https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2019_IRP_Volume_II_Appendices_M-R.pdf.
17 "Glossary of Terms Used In NERC Reliability Standards," North American Electric Reliability Corporation, October 8, 2020, https://www.nerc.com/files/glossary_of_terms.pdf.
18 "T&D Upgrade Deferral," Energy Storage Association Blog, April 24, 2013, http://energystorage.org/energy-storage/technology-applications/td-upgrade-deferral.
19 "Resource Adequacy," Northwest Power and Conservation Council, May 2005k, https://www.nwcouncil.org/sites/default/files/_08__Resource_Adequacy_1.pdf.
20 Anna Chitum and Grace Relf, "Valuing Distributed Energy Resources: Combined Heat and Power and the Modern Grid, 2018," American Council for an Energy Efficient Economy, 2018.
21 "Greenhouse Gas Emissions: Overview of Greenhouse Gasses," United States Environmental Protection Agency, accessed on December 12, 2020, https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

10. Appendix B: Value Methodology

Valuing Customer Benefits

Determining Backup Power Value

The backup power value provided by a solar and battery energy storage is directly related to the offset of cost of fuel, which would normally be consumed by a backup generator. Based on a 50 kW generator capacity, specifications for a diesel[22] and gas[23] fueled backup generators were used to calculate fuel consumption without solar or storage. Backup generator capacities are greater than the typical peak site demands due to various electrical considerations, so most often backup generators run at part load, not full load. For these calculations it was assumed the generator would operate at around 50 percent of its full load rating consistently over a two-week period. Since the generator's efficiency is dependent on the part load operation, the specific efficiency for 50 percent load was used from the manufacturer specifications.

With the efficiency and total energy produced by the backup generator, total fuel consumed over the two-week period, in one million British thermal units (MMBtus), was calculated. Then based on which fuel type, the cost of fuel consumed was calculated. This was between $10/MMBtu and $27/MMBtu, depending on the fuel (e.g. propane, natural gas, diesel). From the Pilot, the solar and battery energy storage systems were offsetting about 70 – 80 percent of the fuel costs at each site. Using the lower end of this range, fuel savings were calculated with a 70 percent offset of the two-week fuel cost calculated for each fuel type. This savings for each fuel type was then normalized on a per kW basis and resulted in a backup power value range of $27/kW to $57/kW of fuel savings per kilowatt of generator capacity per two-week outage.

Valuing Utility Benefits

Determining Total BTM Program Potential

Total capacity potential was determined using the existing Oregon Blue Sky program, which incentivizes customer solar installations, and an average system size derived from the results of the Pilot study. The assumption is that an Oregon Pacific Power battery energy storage program could achieve similar participation as that of the Blue Sky program. As of the June 30, 2020 the number of commercial customers participating in the Oregon Blue Sky program was 864. From this Pilot study, the battery energy storage capacities ranged from 20 kW and 175 kWh to 75 kW and 330 kWh. The Pilot team choose to use 50 kW/200 kWh as an average system size per site as the basis of the calculations[24].

Since these systems would be primarily used for community resiliency, each site would want to reserve a portion of the system capacity for backup power. Reserving 50 percent of the storage capacity for resiliency/backup power would leave 100 kWh available for utility use per participant, and assuming a four-hour discharge duration battery, up to 25 kW of power capacity. Discharge duration is the amount of time that a battery energy storage system can discharge at its rated power without being recharged.

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[22] https://www.generac.com/Industrial/products/diesel-generators/configured/50kw-diesel-generator.
[23] https://www.generac.com/Industrial/products/gaseous-generators/configured/50kw-gaseous-generator_5-4l.
[24] Excluding site #4 due to the preliminary nature of those results.

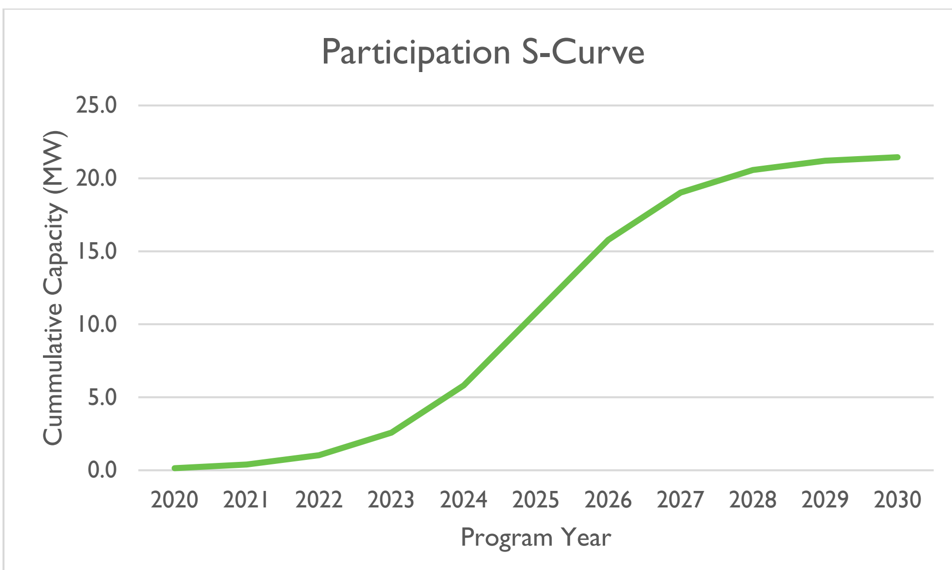
For grid services, which require four hours or less of system availability or operation, the maximum capacity potential is simply the product of the average system's rated power and the total count of participants. The result would be about 22 MW (25 kW/participant x 864 participants).

Annual Participation and Value Projection

After identifying the total potential capacity for grid services, the value of these services and the annual participation was determined using Pacific Power's IRP and an assumption of annual participation capacity over a 10-year period. Ten years was chosen as the evaluation period, as battery energy storage systems typically have at least a ten-year warranty or performance guarantee. Therefore, the utility can count on grid services benefits from even first year participants for 10 years.

In Appendix Q of the IRP, Pacific Power lists the annual benefits streams in $/kW-yr of various grid services. The table below has the capacity benefit rate (in $/kW-yr) for each of the grid services, and the stacked benefits incorporated in this analysis are highlighted.

Next, the annual participant capacity was calculated, assuming it would follow a typical S-curve. An S-curve, or Sigmoidal curve, is an S-shaped curve that predicts how a program might grow over its life cycle. At first, the growth is slow, and then it develops more rapidly, as participants begin to become more aware and familiar with the program, or perhaps as program marketing expands. As the program continues, that growth continues. Eventually, a host of factors, both internal and external, cause the growth rate to decline and then gradually, they taper off. Even for a successful program, this decline is inevitable and is typically due to market saturation where there are fewer and fewer customers that have yet to participate in the program. The chart below illustrates the annual cumulative participant capacity according to an S-curve.



Using the above annual capacity benefit rates and the projected cumulative participant capacity, the total value of grid services each year and over the ten-year period was calculated. The table below has the results for each grid service evaluated.

Program Year	Cumulative Participating Capacity (MW)	Energy Arbitrage	Operating Reserves	Transmission and Distribution Deferral	Resource Adequacy	Total
2020	0.1	$3,076	$5,234	$2,290		$10,600
2021	0.4	$12,700	$21,413	$9,368		$43,482
2022	1	$32,803	$54,753	$23,955		$111,511
2023	2.6	$88,244	$145,603	$63,703		$297,550
2024	5.8	$439,875		$145,346		$585,221
2025	10.8	$898,706		$276,815		$1,175,520
2026	15.8	$1,399,507		$414,203		$1,813,710
2027	19	$1,700,560		$509,449		$2,210,009
2028	20.6	$1,873,690		$564,944	$2,207,884	$4,646,518
2029	21.2	$2,064,445		$594,654	$2,238,736	$4,897,835
2030	21.5	$2,284,696		$616,819	$2,190,598	$5,092,113
Total		**$10,798,302**	**$227,003**	**$3,221,546**	**$6,637,217**	**$20,884,068**

Stackability

The above table calculates a likely mix of stacked grid service values, assuming the entire battery capacity is available to the utility. In other words, it does not account for stacking these values with customer value streams. Balancing the benefits of battery energy storage requires detailed analysis of both the operational characteristics of the battery and the nature of the value streams it captures. Operating batteries to capture stacked benefits could unlock significantly more value than using batteries to pursue individual value streams in isolation. However, there may be technical and operational challenges associated with capturing multiple value streams. To the extent to which energy management systems and software can address these issues is highly variable and dependent on the specific site and application(s). Other barriers may be overcome through new policy initiatives such as offering new or revised rate designs, which more fully reflect the time-varying nature of the cost of generating and delivering electricity, particularly in the Pacific Northwest.

Grid Service	Description	Service Duration	MW Potential	Stackability
Energy Arbitrage	The practice of purchasing and storing electricity during off-peak times, and then utilizing that stored power during periods when electricity prices are the highest.	Hours	22	Low: Requires the system to be able to dynamically adapt to changing pricing.
Resource Adequacy	A condition in which the Region is assured that, in aggregate, utilities or other LSE have acquired sufficient resources to satisfy forecasted future loads reliably.	4+ hours	14	Moderate: Depends if the system provides firm or peaking capacity.
Operating Reserves	Demand that the end-use customer makes available to its load-serving entity via contract or agreement for curtailment.	Minutes to hours	22	Moderate: Depends on the type of ancillary service provided.
Transmission & Distribution Capacity	Defer or avoid the need for a T&D equipment upgrade that is needed due to demand growth.	Hours	22	High: Only needs to meet a portion of the peak demand during a select few hours in the year.

Valuing Societal Benefits: Community Resiliency

The team utilized the FEMA cost benefit analysis tool to understand the value of resiliency for these sites. The FEMA calculations for the specific benefits are explained in further detail below. The following methodology is an example of the FEMA calculations for fire stations.

Avoided Property Loss and Mortality and Injuries Due to a Fire Station Outage

Property loss due to an outage is the difference between the products of a probability of a loss, dollar value of property lost, and number of fire incidents prior to and during the outage. Then, using a national average ratio of total value of mortality and injuries to total property losses due to fires, the value of avoided mortalities and injuries is derived.

Both the probability of loss and the average property value is based on the change in response time. The change in response time is determined by how far the next nearest fire station is to the fire station being evaluated. The further away, the greater the response time, which leads to a larger probability of loss during an outage and the larger average dollar value of property lost during an outage. Further, the number of fire incidents are based on a national average of fire incidents per capita. So, the greater the population the fire station serves, the greater the fire incidents experienced in that community.

For the sites in the Pilot, this avoided property loss value was about $0.25 per person served in the community, and the value of avoided mortality and injury was between about $0.75 to $0.85 per person served in the community.

Avoided Costs Incurred During Complete Loss of Power

When a critical facility loses power completely, the services that facility provides to the community still need to be maintained. This requires emergency measures to be taken to provide these services from another location with power. The cost of these measures depends on the type of facility and the services provided. For critical facilities such as fire stations or shelters, this may be very minimal or have no cost associated, but for hospitals, this may be a very significant cost, such as transporting all patients to other hospitals. For the analysis of the Pilot sites, we assumed $1,000 total avoided cost during a two-week outage. This would account for moving any equipment or personnel to the next nearest facility from which to provide those services to the community.

Avoided Costs Incurred During an Outage

Facilities that can maintain continuous operations through an outage incur costs associated with the operation of the resiliency system. For facilities with conventional backup generators, this is typically the cost of fuel to run the generator during the outage. When a solar and storage resiliency system is used to maintain operations, these costs are avoided. Depending on the fuel type, the rate of avoided fuel costs was between $10/MMBtu and $27/MMBtu. In general, for the sites evaluated, the fuel costs were reduced by about 70 – 80 percent over the two-week outage period.

11. Appendix C: Screening Criteria and Example Scoresheet

Site Name	
Type of Facility	
Site Address	
Community	
General Notes	

	Original Score	Interest Form Score	Differential	Reason for Differential	Post-Audit Score	Differential	Reason for Differential
Pass/Fail							
Commitment to community as a central facility for disaster response		5	N/A			N/A	
Technical & Economic							
Available area at site for storage			0			0	
Data available			0			0	
Expected load growth in area			0			0	
Existing backup generation			0			0	
Funding available to leverage			0			0	
Social and Environmental						0	
Motivated champion/disaster manager exists			0			0	
In/Adjacent to Disaster Imminent or PSPS Zone			0			0	
Existing or planned renewable generation (utility or customer-sited)			0			0	
Renewable generation potential			0			0	
Total Weighted Score (out of 5)	**0.00**	**0.00**	**0.00**		**0.00**	**0.00**	

12. Appendix D: Data Request Checklist

The following table lists the data needed to complete an assessment to determine a site's suitability for battery energy storage in the Community Resiliency Pilot. Some of this data can be obtained by Pacific Power, while others will need to be provided by Pilot participants.

Category / Description	Data Obtained By	Status
Utility Data		
12-24 months of ***Pacific Power*** utility data	Pacific Power	☐ Complete ☐ N/A
12-24 months of ***third-party supplied*** utility data *(if applicable)*	Participant	☐ Complete ☐ N/A
Building Energy Management System trend data *(if available, for specific end-uses or buildings/areas which might be supported in resiliency event)*	Participant	☐ Complete ☐ N/A
Description of known electrical issues *(type of issue and frequency)*	Participant	☐ Complete ☐ N/A
General Site Information		
Type of facility, location, square footage *(n/a, if already supplied in interest form)*	Participant	☐ Complete ☐ N/A
Typical occupancy schedule	Participant	☐ Complete ☐ N/A
Building as-built plans/drawings	Participant	☐ Complete ☐ N/A
Details of any major additions, renovations, or demolitions or equipment replacements or upgrades	Participant	☐ Complete ☐ N/A
Applicable equipment information *(power consumption specifications, operational schedules)*	Participant and/or Pacific Power *(at site audit)*	☐ Complete ☐ N/A
Panel information *(age, capacity, connected loads/equipment)*	Participant and/or Pacific Power *(at site audit)*	☐ Complete ☐ N/A
Capacity and duration *(amount of fuel onsite)* of backup generation	Participant and/or Pacific Power *(at site audit)*	☐ Complete ☐ N/A
Type and capacity of onsite interconnected/operational generation	Participant and/or Pacific Power *(at site audit)*	☐ Complete ☐ N/A

Ideal duration of backup during resiliency event	Participant	☐ Complete ☐ N/A
Area available for storage *(indoors/outdoors, square footage, distance to potential interconnection point)*	Pacific Power *(at site audit)*	☐ Complete ☐ N/A
Area available for generation *(roof age/condition, parking area, ground-mount area, distance to interconnection point)*	Pacific Power *(at site audit)*	☐ Complete ☐ N/A
Environmental and Community Information		
How would the site be used in a resiliency event?	Participant	☐ Complete ☐ N/A
Any community concerns with aesthetics or environmental impacts of potential storage and/or generation	Participant	☐ Complete ☐ N/A

13. Appendix E: Project Profiles

Site #1: Fire Station | Marion County

Site #1 is a fire station located in Marion County, about 35 miles east of Salem. The facility has about 5.5 kW-DC (4.8 kW-AC) of solar on the roof. Current resiliency resources at the site include an 80 kW propane fueled generator. During a disaster, the facility will be used as an assembly area for the community. It will act as a base for emergency operations for the fire protection district and, potentially, other agencies from the community. The facility will be able to provide fire suppression, emergency medical response, hazardous materials response, and fire prevention services to the local community and support such efforts for the larger county area, if necessary.

Most of the end-use loads are considered critical and are on subpanels downstream of automatic transfer switches (ATS). The only equipment (non-critical) not behind an ATS are the air conditioning condensing units and, as a result, would not be available in an outage.

All three levels of resiliency provide benefits to the fire station. The table below shares how the benefits accrue by resiliency level. Battery energy storage provides a more resilient back-up system than a standard backup generator and could pay for itself after a disaster event.

Resiliency Benefits	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Capability to maintain emergency operations during resiliency events	✓	✓	✓
Capable of addressing short-term resiliency events without generator		✓	✓
Reduces dependence on fuel deliveries during an outage		✓	✓
Minimizes carbon emissions			✓

Figure 18: Site 1 – Resiliency Benefits

The analysis was based on a one-time, two-week duration outage and a typical year of normal operations. It investigates what battery energy storage system configuration, paired with the existing propane back-up generator, would be required to maintain facility operations during a two-week outage with minimal fuel, as well as which configuration might provide benefits during normal operations. The following table summarizes the changes to system component sizing, estimated costs, and estimated savings of each resiliency option.

	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Estimated Benefits and Costs*			
Annual Bill Savings	$0	$0	$2,000
One-time Outage Resiliency Benefits**	$1,600	$5,100	$5,600
Capital Costs***	$0	$292,100	$408,100
One-time Outage Fuel Costs	$5,700	$1,800	$1,300
Annual Incremental O&M****	$0	$800	$1,600
System Specifications			
GHG Emissions (lbs CO_2)*****	61,800	43,300	8,400
Backup Generator Capacity (kW)	80	80	80
Solar Capacity (kW)	0	0	55.5
Energy Storage Capacity (kW)	0	75	75
Energy Storage Capacity (kWh)	0	300	300

**All benefits and costs in this report are high-level estimates and should be used for initial planning purposes. Actual costs and benefits should be evaluated when working with storage providers.*

***Resiliency benefits are calculated assuming one two-week disaster event over a 25-year project lifetime.*

****Includes solar, energy storage and backup generator related costs*

*****Includes O&M costs related to new solar, energy storage and/or backup generator equipment*

******Includes annual site emissions from electricity consumption during normal operations and backup generator operation during a two-week outage. **Grid emissions based on Pacific Power's 2019 IRP Projected Emissions***

Figure 19: Site 1 – Benefits & Costs

Site #2: Shelter, Community Center | Wallowa County

Site #2 is a community center located in Wallowa County. The facility has about 44 kW-DC (38 kW-AC) of solar on the roof. There are no permanent resiliency resources at the site, but emergency plans for the facility involve procuring a 75 kW diesel fueled mobile generator. During a disaster, the facility can be used as an assembly area for the community. It may also act as a base for emergency operations for fire and safety or other emergency management agencies from the surrounding areas. Designated shelters are typically able to provide a safe place to sleep, meals, snacks, water, and basic health services such as first aid, help reconnecting with loved ones, and information about other disaster-related resources in the community.

The site has a double throw safety switch, which could be used to connect a mobile generator to supply power to the entire facility in the event of an outage. Therefore, all the end-use loads are considered critical.

All three levels of resiliency provide benefits to the shelter. The below table shares how the benefits accrue by resiliency level. Battery energy storage provides a more resilient back-up system than a standard backup generator and could pay for itself after a disaster event.

Resiliency Benefits	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Capability to maintain emergency operations during resiliency events	✓	✓	✓
Capable of addressing short-term resiliency events without generator		✓	✓
Reduces dependence on fuel deliveries during an outage		✓	✓
Minimizes carbon emissions			✓

Figure 20: Site 2 – Resiliency Benefits

The analysis was based on a one-time two-week duration outage and a typical year of normal operations. It investigates what battery energy storage system configuration, paired with a new diesel back-up generator, would be required to maintain facility operations during a two-week outage with minimal fuel dependency as well as might provide benefits during normal operations. The following table summarizes the changes to system component sizing, estimated costs, and estimated savings of each resiliency option.

	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Estimated Benefits and Costs*			
Annual Bill Savings	$0	$0	$0
One-time Outage Resiliency Benefits**	$7,900	$8,900	$9,200
Capital Costs***	$37,500	$357,700	$421,400
One-time Outage Fuel Costs	$2,100	$800	$400
Annual Incremental O&M****	$2,600	$3,400	$3,400
System Specifications			
GHG Emissions (lbs CO_2)*****	39,800	29,600	26,500
Backup Generator Capacity (kW)	75	75	75
Solar Capacity (kW)	0	0	44
Battery energy storage Capacity (kW)	0	75	75
Battery energy storage Capacity (kWh)	0	330	330

**All benefits and costs in this report are high-level estimates and should be used for initial planning purposes. Actual costs and benefits should be evaluated when working with storage providers.*

***Resiliency benefits are calculated assuming one two-week disaster event over a 25-year project lifetime.*

****Includes solar, battery energy storage and backup generator related costs*

*****Includes O&M costs related to new solar, battery energy storage and/or backup generator equipment*

******Includes annual site emissions from electricity consumption during normal operations and backup generator operation during a two-week outage. **Grid emissions based on Pacific Power's 2019 IRP Projected Emissions***

Figure 21: Site 2 – Benefits & Costs

Site #3: Fire Station | Hood River County

Site #3 is a fire station in Hood River County, about 63 miles east of Portland. Current resiliency resources at the site include a 16 kW natural gas fueled generator. During a disaster, the facility can be used as an assembly area for the community. It will act as a base for emergency operations for the fire protection district and, potentially, other agencies from the community. The facility will be able to provide fire suppression, emergency medical response, hazardous materials response, and fire prevention services to the local community and support such efforts for the larger county area, if necessary.

The site currently is set up to supply power to a subpanel of specific end-uses in the event of an outage. These end-use loads are considered critical and downstream of an ATS. The equipment behind the ATS that would be available in an outage are some lighting, the motorized apparatus bay doors, a refrigerator, and some electric outlets for plug loads.

All three levels of resiliency provide benefits to the fire station. The below table shares how the benefits accrue by resiliency level. Battery energy storage provides a more resilient back-up system than a standard backup generator and could pay for itself after a disaster event.

Resiliency Benefits	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Capability to maintain emergency operations during resiliency events	✓	✓	✓
Capable of addressing short-term resiliency events without generator		✓	✓
Reduces dependence on fuel deliveries during an outage		✓	✓
Minimizes carbon emissions			✓

Figure 22: Site 3 – Resiliency Benefits

The analysis was based on a one-time, two-week duration outage and a typical year of normal operations. It investigates what battery energy storage system configuration, paired with the existing natural gas back-up generator, would be required to maintain facility operations during a two-week outage with minimal fuel dependency as well as might provide benefits during normal operations. The following table summarizes the changes to system component sizing, estimated costs, and estimated savings of each resiliency option.

	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Estimated Benefits and Costs*			
Annual Bill Savings	$0	$500	$2,500
One-time Outage Resiliency Benefits**	$7,700	$7,900	$8,100
Capital Costs***	$0	$174,200	$234,100
One-time Outage Fuel Costs	$600	$300	$200
Annual Incremental O&M****	$0	$200	$700
System Specifications			
GHG Emissions (lbs CO_2)*****	39,000	36,200	7,100
Backup Generator Capacity (kW)	16	16	16
Solar Capacity (kW)	0	0	30
Battery energy storage Capacity (kW)	0	20	20
Battery energy storage Capacity (kWh)	0	175	175

**All benefits and costs in this report are high-level estimates and should be used for initial planning purposes. Actual costs and benefits should be evaluated when working with storage providers.*

***Resiliency benefits are calculated assuming one two-week disaster event over a 25-year project lifetime.*

****Includes solar, battery energy storage and backup generator related costs*

*****Includes O&M costs related to new solar, battery energy storage and/or backup generator equipment*

******Includes annual site emissions from electricity consumption during normal operations and backup generator operation during a two-week outage*. ***Grid emissions based on Pacific Power's 2019 IRP Projected Emissions***

Figure 23: Site 3 – Benefits & Costs

Site #4: Shelter, School | Wasco County

Site #4 is a school in Wasco County, about 63 miles east of Portland. The results of this site are still preliminary. The Pilot team performed a desktop review of available data but was unable to verify existing conditions in the field. There are no permanent resiliency resources at the site. During a disaster, the facility can be used as an assembly area for the community. It may also act as a base for emergency operations for fire and safety or other emergency management agencies from the surrounding areas. Designated shelters are typically able to provide a safe place to sleep, meals, snacks, water, and basic health services such as first aid, help reconnecting with loved ones, and information about other disaster-related resources in the community.

All three levels of resiliency provide benefits to the shelter. The below table shares how the benefits accrue by resiliency level. Battery energy storage provides a more resilient back-up system than a standard backup generator and could pay for itself after a disaster event.

Resiliency Benefits	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Capability to maintain emergency operations during resiliency events	✓	✓	✓
Capable of addressing short-term resiliency events without generator		✓	✓
Reduces dependence on fuel deliveries during an outage		✓	✓
Minimizes carbon emissions			✓

Figure 24: Site 4 – Resiliency Benefits

The analysis was based on a one-time, two-week duration outage and a typical year of normal operations. It investigates what battery energy storage system configuration, paired with a new diesel back-up generator, would be required to maintain facility operations during a two-week outage with minimal fuel dependency as well as might provide benefits during normal operations. The following table summarizes the changes to system component sizing, estimated costs, and estimated savings of each resiliency option.

	Standard Resiliency	Enhanced Resiliency	Comprehensive Resiliency
Estimated Benefits and Costs*			
Annual Bill Savings	$0	$0	$5,500
One-time Outage Resiliency Benefits**	$3,600	$4,600	$5,000
Capital Costs***	$40,000	$519,500	$662,700
One-time Outage Fuel Costs	$2,300	$1,200	$600
Annual Incremental O&M****	$3,500	$4,500	$5,800
System Specifications			
GHG Emissions (lbs CO_2)*****	106,500	102,300	31,600
Backup Generator Capacity (kW)	100	100	100
Solar Capacity (kW)	0	0	75
Battery energy storage Capacity (kW)	0	100	100
Battery energy storage Capacity (kWh)	0	500	500

**All benefits and costs in this report are high-level estimates and should be used for initial planning purposes. Actual costs and benefits should be evaluated when working with storage providers.*

***Resiliency benefits are calculated assuming one two-week disaster event over a 25-year project lifetime.*

****Includes solar, battery energy storage and backup generator related costs*

*****Includes O&M costs related to new solar, battery energy storage and/or backup generator equipment*

******Includes annual site emissions from electricity consumption during normal operations and backup generator operation during a two-week outage.* ***Grid emissions based on Pacific Power's 2019 IRP Projected Emissions***

Figure 25: Site 4 – Benefits & Costs