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A PORTFOLIO MICROGRID IN DENVER, COLORADO

How a multi-use battery energy storage system provides grid and customer services through a public-private partnership

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About Panasonic Corporation of North America

Newark, NJ-based Panasonic Corporation of North America is a leading technology partner and integrator to businesses, government agencies, and consumers across the region. The company is the principal North American subsidiary of Osaka, Japan-based Panasonic Corporation and the hub of Panasonic's U.S. branding, marketing, sales, service, and R&D operations. Panasonic was featured in Fortune Magazine's 2016 ranking of 50 companies that are changing the world and doing well by doing good. Specifically cited were its smart and sustainable technologies, including its contributions to smart cities and the electric vehicle revolution.

For more information, please visit http://www.panasonic.com.

Xcel Energy®

About Xcel Energy

Xcel Energy (NYSE: XEL) provides the energy that powers millions of homes and businesses across eight Western and Midwestern states. Headquartered in Minneapolis, the company is an industry leader in responsibly reducing carbon emissions and producing and delivering clean energy solutions from a variety of renewable sources at competitive prices.

For more information, please visit http://www.xcelenergy.com.

Younicos

About Younicos

Younicos is a pioneer and market leader in game-changing energy and grid solutions based on battery storage. the company provides utilities, independent power producers, microgrids, and C&I customers with turnkey storage systems, supporting a wide range of business opportunities, including frequency response, peak shaving and capacity, integrated photovoltaic-plus-storage solutions, and grid-forming renewable energy systems. Customers benefit from Younicos's unparalleled experience of 150 MW deployed storage, 10 years of R&D at its MW-scale technology centers, and 24/7 O&M services. Younicos is based in Berlin, Germany, and Austin, Texas.

For more information, please visit http://www.younicos.com.

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Introduction

Battery energy storage is rapidly securing a central place in the future of the power grid. The incumbent grid—a system built to provide a one-way flow of power from centralized, predominately fossil-fueled power stations to distant customers—is giving way to a rapidly emerging new system.

Scalable and increasingly cost-competitive renewable energy resources such as solar PV, large-scale wind farms, distributed energy resources, accelerating electric vehicle adoption, and a variety of demand-side capabilities[i] are redefining today's power grid. Multiple trends define the grid's ongoing evolution:

- **Emissions Reduction:** A shift toward more low- and no-carbon electricity sources as renewable energy becomes more affordable and both large system and smaller distributed energy resources become a greater part of today's energy mix.
- **Customer Choice:** Now more than ever, empowered customers have more clean energy and reliability choices, such as solar energy, energy efficiency, electric vehicles, and energy storage. Customers can increasingly adopt new technologies to manage their energy use.
- **Smart, Advanced Grid:** As more energy, such as customer-sited solar energy, is added to the system, the standard of power flow from central electricity generation to the customer is changing. As customers add more renewable generation at their facilities and homes, more advanced communications, control, and devices enable these resources with the appropriate two-way flow of information, services, and value.

This ever-evolving system faces many priorities, including: maintaining grid reliability, strengthening grid resilience, and grid modernization to address the aging of legacy infrastructure—all in the context of a sometimes turbulent regulatory landscape, rate structure reforms, and the rapid pace of technological innovation.

Amidst such a backdrop, energy storage technologies[ii] have shown great promise as the "Swiss army knife" of the power grid, capable of doing many things for many stakeholders. Battery systems in particular are quickly gaining a larger foothold as a flexible, nimble resource that can benefit utilities, customers, and the entire power grid.

[i] Demand-side solutions include, but are not limited to, energy efficiency, demand response programs, and flexible loads such as smart thermostats and grid-interactive water heaters, as well as the advanced metering infrastructure and more-granular rate structures that better enable their grid integration.

[ii] Many different energy storage technologies exist—*Lazard's Levelized Cost of Storage Analysis* evaluates eight—but this paper focuses specifically on lithium ion battery energy storage.

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As Battery Costs Fall, Deployments and Installation Forecasts Begin Scaling

According to GTM Research, the United States deployed 226 megawatts (MW) of storage in 2015, an increase of 251% compared to 2014.[1] Though final 2016 numbers aren't yet in, GTM Research anticipates another 260 MW of storage were installed in the U.S. this past year and forecasts that annual storage deployments will reach 2 GW by 2021,[iii] with front-of-meter, utility-scale storage and behind-the-meter storage sharing the market equally.[2] Lithium-ion technologies dominate in the sector, representing more than 95% of new energy storage deployments in 2015[3] and 95–99% of new deployments during Q1–Q3 2016.[4]

Regulatory mandates and incentives, growing opportunities for market participation—in part a response to the changing electricity generation mix—and the pure economics of falling storage costs have been three major drivers behind these trends:

- **Regulatory mandates and incentives:** Under legislation passed in August, Massachusetts could become the third U.S. state—after California[5] and Oregon[6]—to establish an energy storage mandate.[7] In addition, last year California's Self-Generation Incentive Program [iv] saw proposed reforms that would strengthen its role in supporting that state's energy storage market.[8] At the national level, a proposed federal energy storage tax credit bill was introduced July 2016,[9] modeled after solar's investment tax credit (though the future of that bill is uncertain in the current political landscape).

- **Growing opportunities for market participation:** To date, California and PJM Interconnection (minus New Jersey) have accounted for a whopping 82% of energy storage deployments by MW. But that market share has already fallen from an even higher 92% earlier in 2016,[10] as storage finds expanding opportunities for market participation. For example, in MISO (Midcontinent Independent System Operator) new market rules for storage could go into effect as early as 2017.[11] In 2016, Arizona regulators approved a residential energy storage pilot,[12] while utility Arizona Public Service procured a pair of grid-scale batteries for two communities.[13] "Acceleration" opportunities may also arise, such as the case of Aliso Canyon closure in California prompting an immediate response of deploying 50 MW of storage in 6 months.[14] While in Hawaii, both behind-the-meter and grid-scale storage—including a recent solar+storage project coming in at $0.11/kWh[15]—are fast proving critical for integrating high percentages of solar PV on the grid and for helping that state meet its ambitious 100% renewable energy target.

[iii] For comparison, through Q3 2016 the U.S. had about 75.7 GW of installed wind capacity, according to the American Wind Energy Association, and nearly 40 GW of installed solar PV capacity through Q4 2016, according to the Solar Energy Industries Association.

[iv] California's Self-Generation Incentive Program (SGIP) offers utility customers financial incentives (typically rebates) for the installation of clean and energy-efficient technologies, including advanced energy storage.

- **Falling costs that become competitive with conventional alternatives:** According to Bloomberg New Energy Finance, lithium battery pack costs could fall as low as $182/kilowatt-hour (kWh) by 2025 using current technologies.[16] McKinsey & Company forecasts costs for stationary energy storage could fall faster and further still, to $200/kWh by 2020 and $160/kWh or less in 2025, less than half today's price.[17] Such economic trends are making battery systems more attractive, not just for customers, but for utilities such as Xcel Energy in considering storage as an alternative to investment in conventional power grid infrastructure.

As storage deployments scale under these favorable conditions, utilities and solutions developers are better learning how to leverage these nimble assets to provide value for the electric utility industry and customers.[v] This is a notable shift from even a few short years ago, when utilities and the broader electricity industry were grappling[18] with what these then-emerging and now maturing and fast-growing technologies could mean for customers,[19] demand,[20] and the grid of the future.

Revenue Stacking with Multi-Use Storage Systems Unlock Greater Market Potential

In recent history, battery systems were primarily deployed on the basis of singular use cases serving either a customer or utility, including commercial demand charge reduction, congestion management, backup power, and frequency response. In some markets, storage already provides a financial return in this single-use-case model. For example, energy storage economics based solely on demand charge management are attractive today in seven U.S. states for C&I customers, growing to an estimated 19 states by 2021.[21]

Trailblazing utilities and project developers are now discovering how revenue stacking with multiple value streams can greatly enhance storage system value. In Ohio, for instance, the Village of Minster recently completed a solar-plus-storage system (7 MW / 3 MWh of batteries tied to an adjacent 4.2 MW solar photovoltaic power plant) designed to provide four unique revenue streams: frequency regulation in PJM's market, transmission and distribution system cost deferral, power quality improvement, and demand charge reduction.[22] By contrast, single-use storage deployment typically underutilizes assets when it is not permissible to offer more than one service within the prevailing market design.

[v] Such storage deployment forecasts don't include accelerating electric vehicle (EV) adoption. Bloomberg New Energy Finance expects that EVs will become a more economic option than gasoline or diesel cars in the 2020s and that EVs will account for 35% of new light duty vehicle sales worldwide by 2040. This will add sizeable additional storage to the U.S. grid. And with automakers such as BMW aggregating fleets of its i3 electric car as a demand response resource and Nissan announcing vehicle-to-grid (V2G) capabilities in the next generation of its popular LEAF, battery energy storage via EV could become a part of the U.S. electric grid landscape as well.

As recently demonstrated by Rocky Mountain Institute,[23] GTM Research,[24] and Lazard,[25] battery energy storage systems have the potential to deliver a suite of services, while deploying storage for single-use cases underutilizes these assets and leaves value on the table. Recognizing this potential, the Federal Energy Regulatory Commission (FERC) held a November 2016 conference to focus on exactly this issue: how energy storage could provide multiple services to multiple entities, including across the traditional asset functions of generation, transmission, and distribution; for regional transmission organizations/ independent system operators (RTOs/ISOs), distribution utilities, and other markets; and across wholesale, retail, and/or end-use services.[26] The outcome of FERC's ongoing work on this topic was a proposed rule—announced via a Notice of Proposed Rulemaking (NOPR) November 17[27]—that would unlock storage participation in wholesale energy markets, including via distributed energy resource (DER) aggregation.[28] *Utility Dive* called it a "landmark energy storage rulemaking."[29]

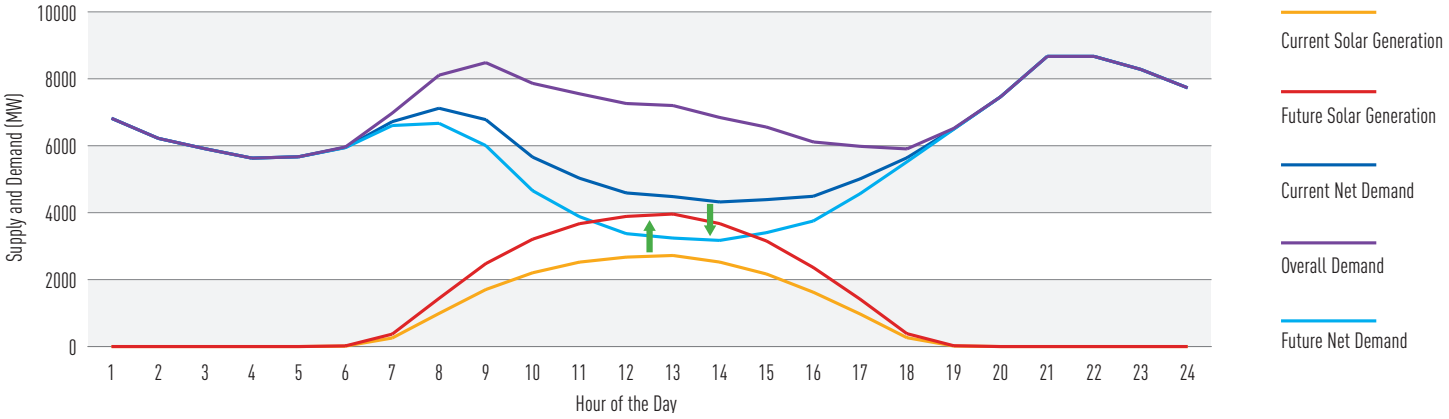
Utilizing such revenue stacking is a key to making storage more widely cost effective *today* under current prices. As storage costs fall, that proposition grows stronger. The battery energy storage project undertaken in partnership by Xcel Energy, Panasonic, Younicos, and Denver International Airport (DEN) at a new transit-oriented development[vi] called Peña Station NEXT, in Denver, Colorado, is one of the latest projects to explore the potential of a multi-use battery energy storage system.

As Renewables Surge in Colorado, Battery Systems Gain Prominence for Aiding Renewables' Grid Integration

In 2004, Colorado voters approved a renewable energy standard (RES)[30] that compelled the state to deploy renewable energy to the "maximum practicable extent."[31] The measure, Amendment 37, anticipated the marked declines in the cost of solar and wind power seen in the years since. In December 2013, for instance, the Colorado Public Utilities Commission (CO PUC) approved a portfolio of new generation capacity submitted by Public Service Company of Colorado (PSC), the state's major investor-owned utility, comprising 450 MW of wind and 170 MW of solar PV expressly because these assets would reduce costs to consumers.[32]

[vi] According to Reconnecting America, a transit-oriented development is "a type of community development that includes a mixture of housing, office, retail and/or other amenities integrated into a walkable neighborhood and located within a half mile of quality public transportation."

Growing Solar PV is Supressing Net Daytime Demand on the Feeder That Serves Peña Station NEXT



Xcel Energy, the parent company of Public Service Company of Colorado, has continued to bring renewable energy online in the state, reducing the power grid's carbon intensity in the process. Between 2005 and 2015, Xcel Energy's CO2 emissions in Colorado declined 24%.[33] Carbon-free electricity accounted for 23% of Xcel Energy's electricity mix in Colorado in 2015,[34] and the utility is on track to exceed the state's updated RES target[35] of 30% by 2020.[36] Earlier this year, Ceres ranked Xcel Energy fourth nationally among investor-owned utilities for renewable energy sales.[37] Some 30,000 customers participate in Xcel Energy's Solar*Rewards program for rooftop installations.[38] Most recently, a major settlement provided Xcel Energy with the green light to pursue, among other initiatives, 340+ MW of new solar capacity between 2017 and 2019,[39] as well as 1,500 MW of new wind capacity.[40] In April the American Wind Energy Association named Xcel Energy the nation's top utility wind energy provider for the 12th consecutive year.[41]

With renewables surging in the state, many parties—including Xcel Energy and Panasonic—have a keen interest in advancing solutions that aid grid integration, both to support the grid and sustain technological and market opportunities for renewables' continued growth. Peña Station NEXT is becoming an anchor for proving the value of such solutions.

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Peña Station NEXT Becomes a Proving Ground for Battery and Other Technologies

Peña Station NEXT is a 382-acre transit-oriented development adjacent to the Regional Transportation District's 61st & Peña rail station, located along the University of Colorado A Line train linking downtown Denver with Denver International Airport (DEN). The route opened in April 2016 as part of one of the largest public transit expansions in the U.S. Located a short distance southwest of the airport proper along the Peña Boulevard corridor, Peña Station NEXT is also one of the first major steps toward realizing Colorado's vision of creating a "live, work, play" aerotropolis—or "airport city"—around DEN.

Phase 1 of the public-private partnership is adjacent to the 61st and Peña rail station and includes an 800-space parking lot for the station on Denver International Airport land, roads and infrastructure, the new technology and operations hub for Panasonic Enterprise Solutions Company and Panasonic CityNOW, a hotel, an apartment complex, and—coming to the site temporarily in October 2017—the U.S. Solar Decathlon competition, a biennial international solar home design competition among more than a dozen collegiate teams and sponsored by the U.S. Department of Energy. The development is located on an Xcel Energy feeder that already has 20% solar penetration[vii]; this level expected to increase to 30% by the time project is completed in Q1 2017.[viii]

Peña Station NEXT will feature a variety of smart and sustainable solutions, with Panasonic serving as the lead technology partner. Solutions include smart street lighting, ultra-fast community Wi-Fi, smart parking, electric vehicle charging stations, autonomous electric, a smart bus shelter, environmental sensing, interactive digital signage, and the solar-plus-storage microgrid that is the focus of this paper.[42]

Peña Station NEXT serves as a proving ground for these and other smart and sustainable technologies prior to their deployment more broadly throughout either Xcel Energy's service territory in Colorado and/or by the City and County of Denver.

[vii] Locally, Peña Station NEXT will be net-positive energy with substantial surplus solar until enough of the development is built out for demand to absorb the solar generation.

[viii] Degree of solar penetration is defined as distributed solar PV generation as a percent of distribution feeder peak demand. Some utilities, such as Hawaiian Electric (HECO), instead convey distributed solar PV penetration as a percent of daytime minimum load.

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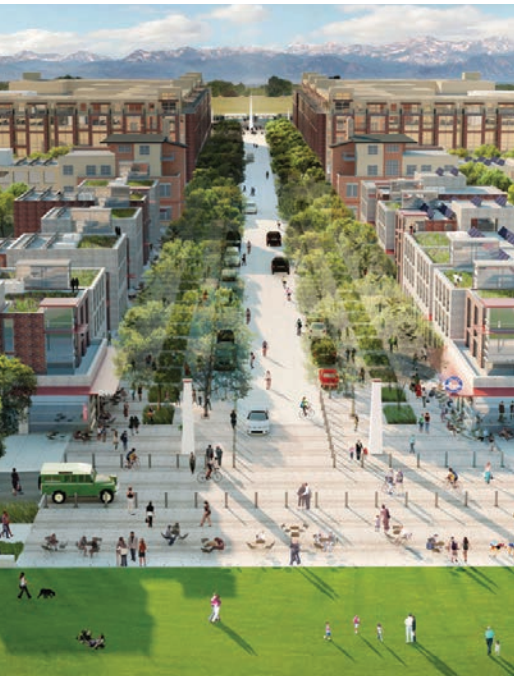
Smart Cities, Clean Energy, and Sustainability at Panasonic

Panasonic CityNOW brings Panasonic's global smart city expertise to North America. The program is an engine for smart and sustainable innovation and growth, from iconic developments and neighborhoods to entire districts and cities. Its first major North American project is Peña Station NEXT in Denver, inspired by Fujisawa Sustainable Smart Town,[43] a Panasonic-led development in Japan about 30 miles SW of Tokyo. CityNOW focuses on transformational, human-centric solutions across five core pillars: clean energy, smart mobility, city services and public safety, smart buildings, and health and wellness.

CityNOW delivers holistic, integrated clean energy solutions, including energy and sustainability analyses and planning, solar PV, battery energy storage, smart buildings, energy efficiency technologies, demand-side management, and microgrid applications. Both the Energy Solutions Group of Panasonic Enterprise Solutions Company and Coronal Energy, powered by Panasonic, contribute to CityNOW's solutions portfolio and delivery capability, with a focus on tailored customer-centric renewable energy solutions for utilities, large corporations and developments, government agencies, and educational institutions.

In Interbrand's latest biennial "Best Global Green Brands" report (2014), Panasonic ranked number five overall and the top electronics brand in the report. As part of continuing sustainability efforts, Panasonic Corporation of North America relocated its headquarters to a new facility, adjacent to Newark Penn Station in Newark, N.J. It is the first newly constructed office tower in Newark to earn both LEED Platinum and Gold certifications from the U.S. Green Building Council. The Denver operations hub for Panasonic CityNOW and Panasonic Enterprise Solutions Company similarly is targeting LEED Gold with a net-positive energy profile.



A Public-Private Partnership Yields a Portfolio Microgrid

Microgrids,[ix] especially in the U.S., are often confined by the boundaries—geographic and metaphorical—of a single entity, such as a university campus or a military base.[44] Yet a recent shift away from single-entity microgrids toward multi-stakeholder microgrid models is improving both project economics and growth expectations.[45] At Peña Station NEXT in particular, the public-private partnership approach has resulted in a different model we think of as a "portfolio microgrid" on three levels: a) a portfolio of stakeholders, b) a portfolio of assets, and c) a portfolio of benefits/services.

[ix] According to the U.S. Department of Energy Microgrid Exchange Group, "a microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that … can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."

Portfolio of Stakeholders

- **Xcel Energy:** Colorado's major investor-owned utility, in 2016 Xcel Energy unveiled *Our Energy Future*,[46] a vision for the state's energy system based on three key objectives: a) powering technology (with emerging environmentally and technically superior tools), b) powering the economy (with a modern power grid and renewable energy), and c) empowering customer choice (including through new solar offerings and rate designs). The Panasonic microgrid project at Peña Station NEXT is one of two solar-to-battery projects that are part of the initiative.

- **Younicos:** Based upon a long experience of microgrid simulation and analysis at its technology centers, Younicos recognizes that intelligent energy management embedded within an energy storage system can play an integral part in managing microgrid reliability, particularly in systems where renewable energy sources are intended to form a substantial part of the power supply. With deep expertise in MW-scale battery energy storage and storage software applications, Younicos is able to both provide important value to the Peña Station NEXT microgrid with the company's advanced energy storage solution and learn lessons from the battery system's stacked use cases.

- **City and County of Denver (Denver) and Denver International Airport (DEN):** Denver and DEN, which is owned and operated by Denver, have aggressive sustainability goals, including 80% greenhouse gas reduction by 2050[47] and 50% fossil fuel reduction by 2020[48] targets. DEN was the fourth U.S. airport group to be recognized by the Airport Carbon Accreditation program, an international program to measure, manage, and reduce airport greenhouse gas emissions. The Peña Station NEXT project becomes a showcase for how microgrid and battery elements may support the airport's future growth in aviation and commercial activities by improving the resilience and sustainability of critical DEN assets and better integrating the airport's loads with the surrounding grid.

- **L.C. Fulenwider, Inc.:** A real estate pioneer in Colorado since 1904, L.C. Fulenwider, Inc. is the master real estate developer at Peña Station NEXT and deeply committed to sustainability. The firm is passionate about the value-add the microgrid and microgrid-ready infrastructure can provide to attract and retain future tenants at Peña and other future developments.

- **Panasonic:** After initial consideration of more than 20 U.S. cities, in December 2014 Panasonic Corporation of North America announced[49] it would consolidate its Panasonic Enterprise Solutions Company and Panasonic CityNOW into a new operations hub in Denver in close partnership with the City and County of Denver, Xcel Energy, and others. At Peña Station NEXT, Panasonic thus became the anchor corporate tenant, smart and sustainable technologies lead, and—announced in September 2016[50]—an invested equity partner in the development.

Xcel Energy's retail customers in Colorado—both on the same feeder circuit as Peña Station NEXT and beyond it—as well as Denver's residents are additional stakeholders who will also benefit as a result of lessons learned at Peña.

Portfolio of Assets

The battery system project at Peña Station NEXT, approved by the Colorado Public Utilities Commission (CO PUC) in March 2016, is a pilot under Xcel Energy's $10.3 million battery demonstration through its Colorado Innovative Clean Technology (ICT) program. The ICT program—originally approved by CO PUC in 2009—allows Xcel Energy to test emerging energy technologies that can potentially lower GHG emissions and provide other environmental benefits. ICT pilots also allow Xcel Energy to evaluate a technology's cost, reliability, and environmental performance on a smaller demonstration scale before considering additional deployments.

The Peña Station NEXT microgrid project comprises five core elements:

- **1.6 MW_{dc} carport solar PV installation:** located over the Denver International Airport parking lot; DEN will own the carport canopy structure, while Xcel Energy will own the solar PV system and operate it under a long-term lease agreement with DEN; offers additional, non-energy benefits such as covered parking; importantly, the solar carport is *not* behind the microgrid islanding switch, though the battery energy storage system that anchors the microgrid is performing its use case operations by including real-time data from the solar carport to evaluate when and how to charge and discharge
- **259 kW_{dc} rooftop solar PV array:** installed atop Panasonic's corporate office building using Panasonic HIT solar PV modules
- **1 MW / 2 MWh lithium ion battery system:** the battery system, including inverter and controls, will be installed by Younicos at Panasonic's building in an outdoor-rated enclosure; Xcel Energy will own and operate the battery energy storage system, while Panasonic will perform the operations and maintenance in concert with Younicos
- **Panasonic's Denver operations hub building:** will serve as the initial anchor load for the microgrid; a high-tech, energy-efficient office targeting LEED Gold and net-positive energy, with an intelligent building energy management system
- **Switching and control systems:** to operate the battery energy storage system and microgrid functionality

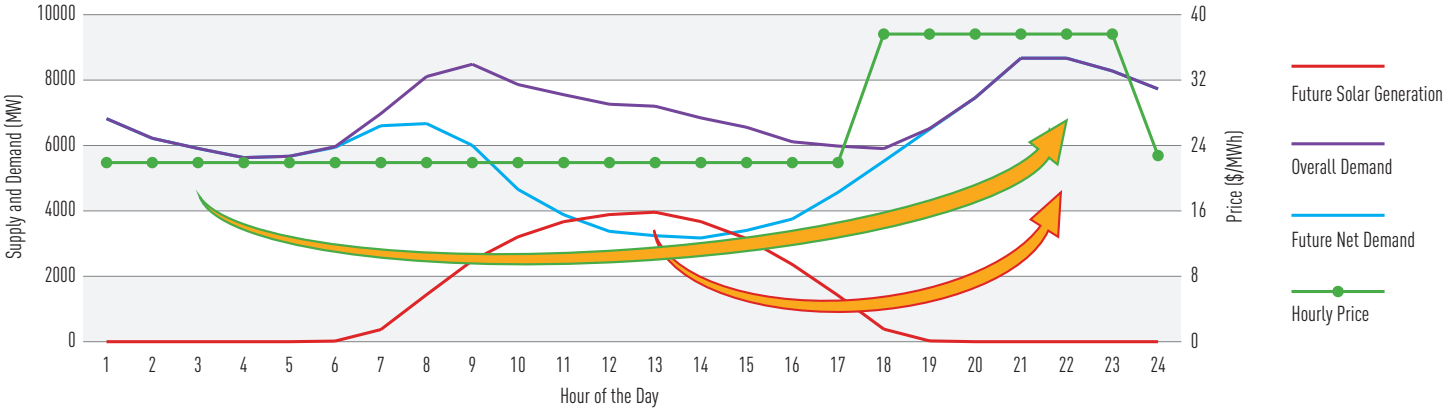
Project partners are contributing nearly $4 million toward the demonstration —$2.7 million from DEN for ownership of the carport and $1.7 million from Panasonic for the rooftop solar PV system and in preferential pricing in construction, maintenance, and labor for the carport solar PV system and battery, but not including the cost of Panasonic's new facility.

Portfolio of Benefits/Services

The battery system at Peña Station NEXT will be leveraged for five major use cases whose services and benefits accrue to different combinations of the core stakeholders:

- **Solar Grid Integration:** Better grid integration of high-penetration solar PV actually comprises two related but distinct use cases, which operate on different time scales and which call upon the battery's capacity and state of charge to different degrees.
  - **Ramp Control for Solar Smoothing:** In this instance, the battery system charges and discharges to manage (i.e., minimize) rapid fluctuations in solar PV output, monitoring both Panasonic's behind-the-meter rooftop solar PV system and the carport's solar PV. The battery system limits the solar ramp rate to about 10% of the solar PV's total capacity (carport plus rooftop). This equates to limits of approximately -180 kW/min to +180 kW/min. The net charge and discharge of the battery in this case is relatively small, especially compared to bulk solar time shifting described next.
  - **Solar Time Shifting:** In short, solar time shifting stores excess energy when solar generation output is high and dispatches that energy later in the day. This approach helps manage loads on the feeder, preventing potential backflow during times of surplus solar generation and reducing peak demand by better aligning solar generation with the daily electricity demand curve on this feeder.
- **Grid Peak Demand Reduction:** This use case is based on reducing peak demand on Xcel Energy's system, not based on reducing the peak demand of an individual commercial customer for purpose of managing demand charges. This case will be event-based, set to charge and—more importantly—discharge the battery based on certain times of year when historical data sets have shown Xcel Energy's grid to exhibit high demand, such as hot summer afternoons when air conditioning load creates additional demand on the system. Xcel Energy will likely call upon this use case 10–15 times per year.

Solar Time Shifting and Energy Arbitrage Use Cases Move Inexpensive, Off-peak kWh and Solar Generation Into Higher-Price, On-peak Hours



- **Energy Arbitrage:** This use case is fairly straightforward—charge the battery when prices are low, discharge when prices are high.[x] The battery will start charging from the grid when an energy price signal (in terms of $/kWh) is lower than a low-price threshold. Likewise, it will discharge when those energy price signals are higher than a high-price threshold. Similar to the grid peak demand reduction and solar time shifting use cases, this case can be thought of as a form of energy time shifting, but doing so on the basis of price rather than generation (solar time shifting) or demand (grid peak demand reduction).

  Because solar PV generation peaks earlier than demand on Xcel Energy's grid and energy prices typically bottom out overnight after peak demand subsides, both the solar time shifting and energy arbitrage use cases have the net effect of regularly shifting energy produced earlier in the day—whether from the on-site solar or from the grid—into the peak demand period to help moderate the supply/demand balance. Meanwhile, the grid peak demand reduction case could involve a much deeper discharge of the battery to offset the highest cases of feeder demand a limited number of times per year.

- **Frequency Regulation:** In this use case, the battery provides frequency regulation as part of ancillary services, providing a fast-responding resource that can potentially deliver relatively high value without compromising other use cases for the battery. This use case has broader relevance, not just for grid operations, but also for customers with strict power quality needs, such as data centers and high-tech manufacturers. In this instance, it will serve a semi-primary/secondary type of frequency response role (i.e., respond when

[x] Because Colorado does not have an open wholesale electricity market, Xcel Energy internally sets "artificial" price signals in 15-minute increments based on its generation costs to evaluate this use case at Peña Station NEXT.

frequency deviates from a defined limit). Frequency will be measured at the point of common coupling (PCC) of the battery, Panasonic's facility, and the microgrid islanding switch. Though this battery system alone is insufficient to provide truly meaningful levels of frequency regulation, it will provide useful insight into how aggregated fleets of such assets could do so.

- **Resilience Through Backup Power:** Panasonic's facility includes a new, state-of-the-art network operations center (NOC) at which it conducts real-time monitoring and management of a nationwide network of solar PV assets. Hence, maintaining essentially 24/7/365 uptime and connectivity is critical. A to-be-determined portion of the battery's capacity—initially targeting 20% but to be revised—will therefore be reserved to provide an estimated four hours of backup power to the facility under special contract with Panasonic. This reserved capacity was included in calculations for overall sizing the 1 MW / 2 MWh specifications for the battery system.

  An islanding switch puts the battery, Panasonic's rooftop PV, and Panasonic's facility into grid-forming mode. Excess rooftop PV generation can charge the battery to extend the duration of microgrid mode in the event of prolonged grid outage. Panasonic's building also has an intelligent energy management system that will prioritize and shed non-critical loads if it senses the battery drawing down. Upon return of the grid to stable conditions, Younicos's energy storage inverter controller synchronizes with the grid, permitting the islanding switch to perform a closed transition back to grid. To ensure grid stability, the grid must maintain a steady state before the microgrid leaves islanding mode.

  Xcel Energy is also evaluating this model as a potential alternative for offering customers another backup power option versus the current state of access to an alternate feeder via line extensions and the use of automatic throw-over (ATO) switches. This has the potential to be appealing to customers in remote locations, where alternatives are otherwise cost prohibitive, or where the battery and microgrid provide additional desirable benefits beyond resilience (e.g., with renewables integration).

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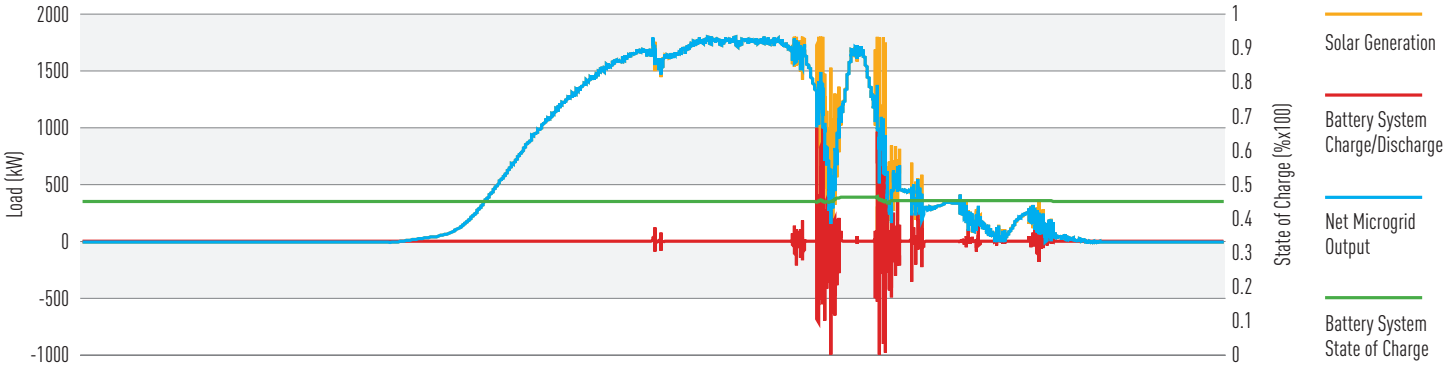
Determining Optimal Battery Deployment via Complementary Value Propositions is Complex

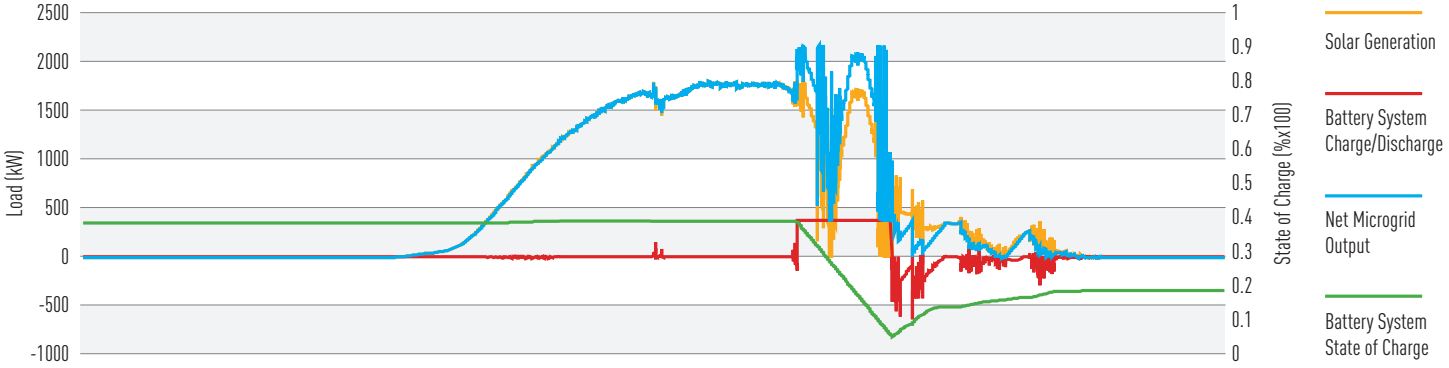
The ultimate goal of the two-year battery pilot at the Peña Station NEXT microgrid is to examine complementary value propositions for storage. It is a complex process at best, defining use case hierarchies and priorities: some can operate in tandem/parallel, some must operate sequentially but are otherwise mutually exclusive at any particular point in time.

A testing schedule for the project will leverage advanced controls in the energy storage system to alternate different operations with different priorities. This will enable evaluation of different use case hierarchies to determine optimal settings for the battery, as well as business models that could support deployment of similar such microgrids in Colorado and beyond.

Solar Ramp Control (Graphed) and Frequency Regulation Use Cases Involve Only a Small Net Change in the Battery System's State of Charge



Grid Peak Demand Reduction (Graphed) and Backup Power Use Cases Involve a Much Larger Net Change in the Battery System's State of Charge



Conclusion and Looking Forward

Multi-use battery systems—including the lithium ion battery energy storage system at Peña—are an exciting, promise-filled technology and solution. Despite the opportunities, the relative nascence of storage technology as a stationary grid resource means there are to date limited information and guidance on the analysis, economics, and technological factors of deployment. While Colorado does not currently have open markets for all power grid services that might benefit from battery energy storage, testing at the Peña Station NEXT microgrid will inform Xcel Energy, Panasonic, and Younicos on potential paths forward.

Once the microgrid is live in early 2017, Xcel Energy, Panasonic, Younicos, and the other project partners will gather data to review real-world performance and make refinements over time. After completion of the two-year pilot, the project partners will analyze the battery system performance data to determine the optimal settings for the remainder of the battery's estimated 10-year life span.

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Footnotes

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