Blackout Provides Real-World Test for Resilient DERs

prepared for

NYSERDA

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1 Introduction

Distributed energy resources (DERs) – including solar photovoltaics, energy storage, fuel cells, combined heat and power (CHP) systems, and others – promise three key values: greater efficiency, reduced carbon emissions, and enhanced resiliency. While the economic and efficiency benefits of DERs are well understood, the resiliency benefits offered by DERs have been more hypothetical.

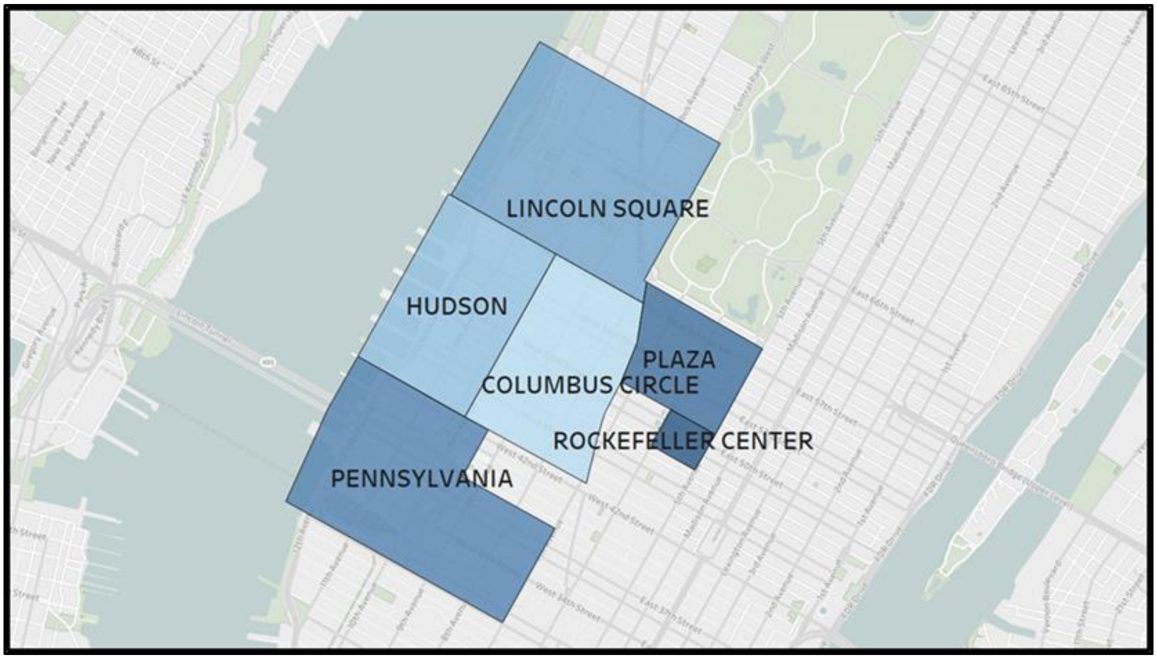
On July 13, 2019, parts of six Con Edison networks in Manhattan lost power for approximately 5 hours, impacting 72,000 utility customers. The affected area included 33 DER systems that were installed with the assistance of NYSERDA incentives, representing a rare test case to evaluate the realized potential of resilient DERs. The impacted installations hosted technologies across the resilient DER spectrum, including battery energy storage, fuel cells, and CHP units, many of which stream high-quality, high-resolution, near-real-time performance data to NYSERDA's Distributed Energy Resources Integrated Data System (DERIDS, https://der.nyserda.ny.gov).

The electric grid in the United States is robust, providing few recent, significant power outage data points to understand the resiliency performance of DERs in emergency, grid-isolated conditions. With this unique real-life opportunity, and on behalf of NYSERDA, ERS completed quantitative resiliency performance analyses for these systems and conducted in-depth qualitative interviews with DER system operators. We uncovered many surprising pain points and lessons learned that cut across the industry. We'll share insights into what worked and what didn't. We will discuss why things failed when they were most needed and share what new best practices will help resilient DERs achieve their full potential..

1.1 Overview of the Event

On July 13, 2019, beginning at 6:47 p.m., approximately 72,000 utility customers in Manhattan lost electric service. The outage event impacted customers in six Con Edison electric networks (Lincoln Square, Rockefeller Center, Plaza, Hudson, Columbus Circle, and Pennsylvania networks). Not all customers in these networks experienced power outages; however, in three of the areas (Lincoln Square, Rockefeller Center, and Plaza networks), more than 15% of customers experienced an outage more than 3 hours in duration. Figure 1, below, is a map that shows where the six impacted Manhattan networks are located.

Figure 1. Con Edison Distribution Networks in Midtown Manhattan[1]



[1] The Lincoln Square, Rockefeller Center, Plaza, Hudson, Columbus Circle, and Pennsylvania networks were affected by a utility service outage on July 13, 2019.

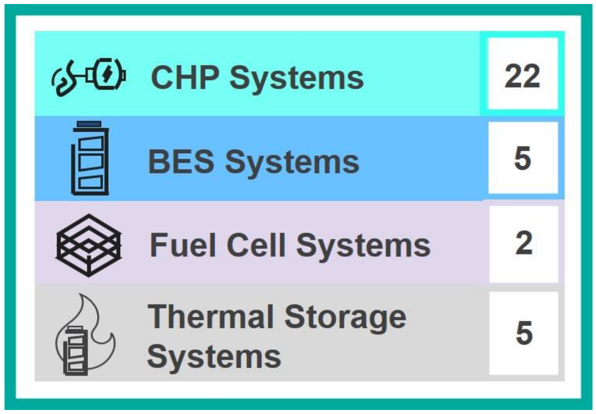
Con Edison has determined that the outage began at 6:47 p.m. when a distribution feeder experienced an electrical fault in a manhole near the West 65th Street Area Substation. The relays on distribution feeder 35261 operated as designed to isolate the electrical fault to that feeder; however, three protective relays on transformers at that substation simultaneously mis-operated in response to the fault on the feeder, which caused a cascading loss of power across six networks.

Based on performance data available from NYSERDA's DERIDS website, some customers experienced outages as a direct result of the electrical fault at 6:47 p.m., while others experienced power loss later (beginning between 9:00 and 9:30 p.m.), likely as a result of Con Edison emergency repair activities. Power was fully restored to all customers by 11:37 p.m.

1.2 NYSERDA DERs Affected by the Power Outage

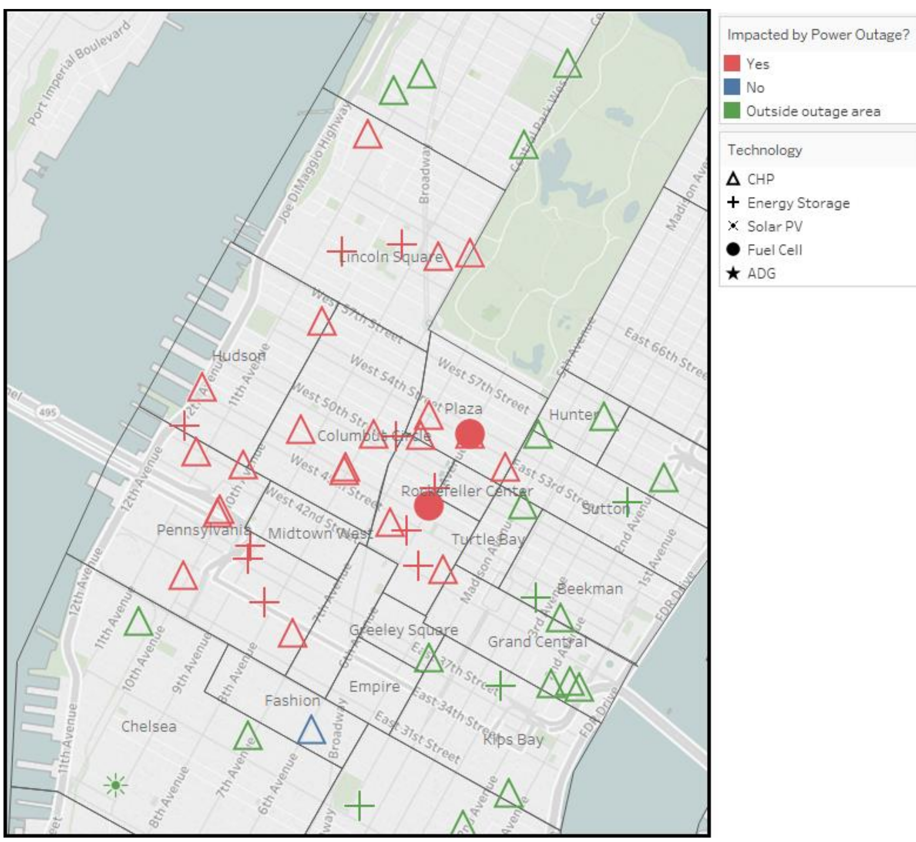
In total, 33 DERs installed with the assistance of NYSERDA incentives were located at host facilities that were impacted by the July 13 Con Edison power outage. These include several different types of DER technology, including:

Figure 2. NYSERDA-Incentivized DER Systems Affected by July 13 Power Outage



One site included both a CHP and a fuel cell system. The five BES systems do not currently report data to the DERIDS site but were configured to provide standby power; this may be an interesting topic for future research. Thermal energy storage systems do not provide resiliency value to host facilities unless they have been configured to remain operational during a grid outage with the assistance of resilient DERs. Figure 3 provides an overview of the installations and types of systems impacted by the power outage.

Figure 3. NYSERDA-Incentivized DER Systems Affected by July 13 Power Outage Overlaid with Con Edison Distribution Network Map



CHP and fuel cell projects that are installed with NYSERDA assistance are required to submit performance data to NYSERDA's DERIDS website for a minimum of three years. Of the 24 CHP and fuel cell installations in the affected area, 7 systems were no longer reporting data, 4 reported data of insufficient quality to support conclusions about their performance, and 13 CHP systems were reporting high quality data during the power outage. These 13 CHP systems were all configured to provide standby power to priority loads during utility outages.

1.3 ERS Resiliency Performance Analysis Methodology

To identify which sites were impacted by the July 13 Manhattan power outage, ERS tracked media reports to identify the approximate outage area. As previously discussed, the outage impacted six Con Edison electric networks (Lincoln Square, Rockefeller Center, Plaza, Hudson, Columbus Circle, and Pennsylvania networks). Leveraging NYSERDA program data, ERS pulled a master list of DER installations from the DERIDS website that included relevant site metadata such as the site name, address, latitude and longitude, and installation characteristics. To visualize the DER sites within the impacted networks, this metadata was plotted on a Tableau geospatial dashboard created by ERS with an overlay of the Con Edison electric network layer on a geographic map (as shown in Figure 3, above).

ERS staff called sites in the affected networks, from the outage origin point outwards, to confirm whether the site had lost power during the blackout. This included contacting sites that were also near-to-but-outside-of the reported six impacted networks to fully identify the geographical limits of the outage; in some cases, we were able to identify impacted sites that lost power outside of the reported six networks. Using these site contacts, we established a "black-out boundary" that lay slightly outside of the north, east, and south sides of the six networks (the boundary to the west is the Hudson River). In total, ERS identified 33 sites with NYSERDA-incentivized DERs that lost power.

With a short site list identified, we initially employed the DERIDS portal performance data to analyze system performance during the outage. However, as the data available from the portal is presented at hourly resolution, we were not able to draw clear conclusions as to how each CHP system operated in response to the power outage.

To obtain better insight, we engaged with the DERIDS data aggregation contractor, Frontier Energy, to obtain the raw performance data for each of the systems for which performance data was available for the 24-hour period from 7/13/2019 11:00 a.m. EST to 7/14/2019 11:00 a.m. EST. This "fundamental" data is directly transmitted to Frontier Energy by CHP operators through on-site M&V data acquisition systems. The ultimate performance data resolution varied site-by-site from 1-minute to 15-minute timestamps.

We used two data channels in this performance analysis – the power generated by the CHP systems and the power imported from the utility – as a proxy to identify the individual start and end time of the outage per site. The utility import data indicated that the power outage at some of the identified DER sites began later (starting between 9:00 and 9:30 p.m. EST) than would have been expected, likely as a result of maintenance operations by Con Edison. We analyzed and plotted system performance in the 24-hour period that encompassed the power outage. This included developing visualization tools to overlay multiple data streams on the same plot to aid visual review.

1.4 Summary of CHP Performance During the Power Outage

We were able to draw conclusions about the performance of the 13 CHP systems that were both configured to provide standby power during a utility outage and that reported sufficiently high-quality data during the July 13 power outage. Table 1 provides a summary of the standby power performance of these systems. Island Transfer Type refers to the method employed by the site to switch between grid-connected or islanded operation modes. While there are multiple options, choices here are broadly broken into two categories: automatic transfer switch (ATS) and manual transfer switch (MTS) schemes. One site (labeled "Hybrid") employed both. "N/V" refers to a site whose island transfer type was not verifiable based on project documentation.

Table 1. Summary of CHP System Performance during July 13 Manhattan Power Outage

Standby Power Performance	Industry	Size (kW)	Island Transfer Type
Performed as expected[1]	Multifamily	200	ATS
Some performance[2]	Multifamily	100	MTS
Some performance[2]	Multifamily	100	MTS
Did not restart	Mailing/shipping	800	ATS
Did not restart	Inpatient mental health	65	N/V
Did not restart	Mixed-use office	1,200	ATS
Did not restart	Entertainment or cultural	300	ATS
Did not restart	Hotel	750	N/V
Did not restart	Multifamily	225	Hybrid
Did not restart	Hotel	325	ATS
Did not restart	Hotel	130	ATS
Did not restart	Multifamily	100	ATS
Did not restart	Multifamily	160	MTS

[1] "Performed as expected" indicates that the CHP system turned off when the grid went down and, afterwards, disconnected from the grid and restarted to provide priority power to the building's standby power loads.

[2] "Some performance" indicates that the CHP system was able to restart and provide priority power to the building, but that operation was unstable, and the engine was unable to provide power for the duration of the outage.

Unfortunately, overall standby power performance of the CHP systems in the impacted outage area was very poor. Only one system, a 200 kW CHP system installed at a multifamily residence building, performed as expected. Two additional systems, co-located at the same multifamily residence building, were able to island and restart but quickly shut down to prevent overheating – their heat rejection systems had failed.

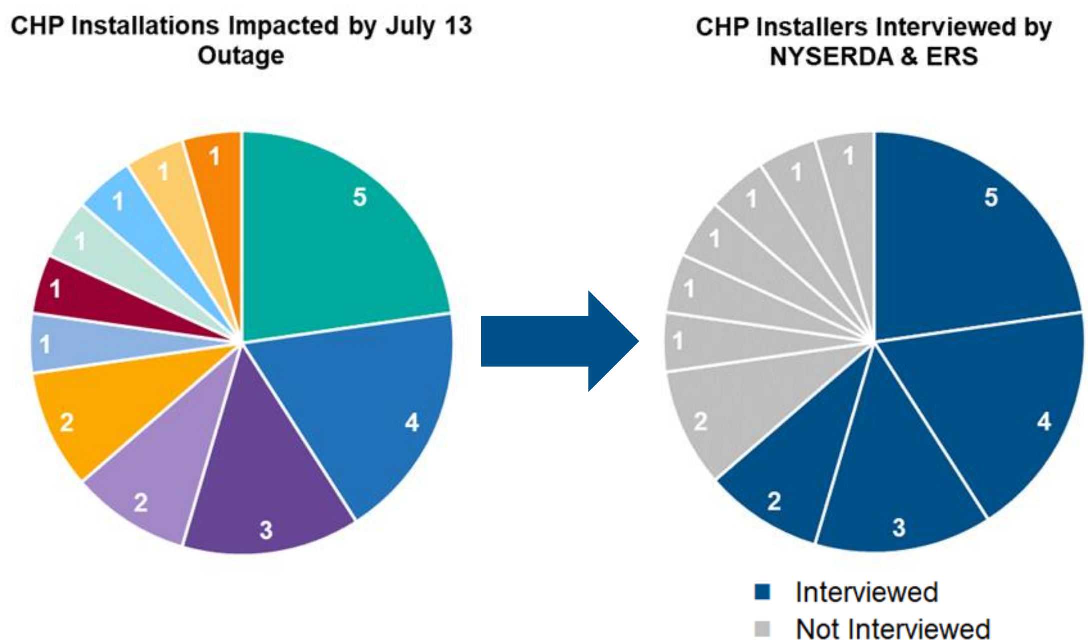
The remaining 10 CHP systems were not able to restart until grid power had been restored to their facilities; they provided no standby power during the grid outage. We had theorized that there would be significant performance discrepancies by system operator or grid interconnection type – in particular between manual transition interconnects (which require on-site operators to complete multiple instruction steps in a particular order throughout the building) and automatic transition systems (which can operate without human intervention); however, there were no clear performance trends that emerged after analysis of performance data. Resiliency challenges appear to have been widespread, including broad swathes of CHP solution providers, host facilities, and interconnection transfer types. To move beyond the "what happened" analysis from remote performance data, the team spoke directly with CHP system operators and facility representatives to understand the root cause of failures, detailed in the section below. We leveraged these conversations to develop recommendations for resiliency best practices that could be adopted to ensure greater chances of success, included in Conclusions and Recommendations.

2 Vendor Interviews

To identify the root causes and develop a nuanced, holistic understanding of the failure modes for these systems beyond what data analytics could provide, NYSERDA and ERS engaged in collaborative interviews with a selection of system operators that were impacted by the July 13 power outage. By learning the first-hand perspective of those who were directly affected by the outage and were attempting to get the systems back on, we were able to develop an understanding of why systems failed to restart and explore solutions that may improve performance in future widespread power interruption events. In each 60–90 minute interview, we discussed our findings from the analysis phase, compared those against the vendors' own data, and spoke broadly about what contributed to the success or failure of each site. As a follow-on, we identified specific actions that could be taken to prevent those situations from occurring in the future. For example, if the issues were caused by unexpected equipment failure, NYSERDA and the vendor community could develop best practices for preventative maintenance or active monitoring procedures that would keep equipment functioning as expected. If the issues were rooted in training oversights, communication challenges, or lack of available staff on-site to island and restart the CHP systems, NYSERDA and the vendor community could develop training guidelines or additional business offerings that will address this issue. Interviews also focused on the customer perspective. Some, but not all, of these systems had been installed specifically to provide resiliency, so NYSERDA and ERS asked if these customers were frustrated by the widespread lack of standby power performance.

As previously discussed in NYSERDA DERs Affected by the Power Outage, we identified 22 CHP systems at facilities impacted by the July 13 power outage, spread across 15 installers and/or operators, although high quality data was only available for 13 systems. NYSERDA ultimately chose to interview only four CHP installer/operators. Although only 27% of the potential operator pool was interviewed, these four firms represented the majority of the systems impacted – they had acted either as the system installer or the system operator for 63% of the total sites, as documented in Figure 4.

Figure 4. CHP Installations Impacted by Outage & Interviewed, Grouped by Installer



Through these in-depth interviews, NYSERDA and ERS were able to identify several common causes of black-start system failure.

2.1 Interview Findings

Each building equipped with a black start-capable CHP system encountered unique challenges in realizing grid-independent priority power. Across all systems operated by the interviewed vendors, we determined that the root cause of standby power failures could be broken into three broad groups: process issues (focused on communications), equipment (individual component failures), and design. Table 2, below, summarizes the high-level findings from the collaborative interview sessions with NYSERDA. Although four parties were interviewed by NYSERDA and ERS, the table below breaks out the sites by the five system operators represented in this pool (a CHP system may have been installed by one company and operated by another). The sites listed below do not necessarily correlate with those in Table 1.

Table 2. Breakdown of Issues Identified during Vendor Interviews

Site Industry	Operator	Process Issues	Equipment Issues	Design Issues
Multifamily	Operator A		X	
Multifamily	Operator A	X	X	
Multifamily	Operator B	X		
Mailing / shipping	Operator C	X	X	
Mixed-use office	Operator C	X	X	
Hotel	Operator C	X		X
Hotel	Operator C	X		X
Multifamily	Operator D		X	
Multifamily	Operator D	X	X	
Multifamily	Operator D	X	X	
Multifamily	Operator E		X	
Entertainment or cultural	Operator E	X		X

In each case, the challenges experienced by each site were unique – and the majority of sites experienced more than one type of challenge.

- **Process issues** relate to breakdowns in training or communications (either person-to-person or digital) that prevented pre-established protocols from being implemented.
- **Equipment issues** include instances where equipment failure – all preexisting failures that had not yet been identified or addressed – prevented the CHP systems from either correctly restarting or sustaining stable operation.
- Unexpectedly, a small number of sites experienced failures that could only be described as **design issues**, where fundamental issues in design and implementation meant that the associated systems were not built to provide meaningful resiliency even if they had operated. These are larger scale issues stemming from a disconnect between the CHP program design, code requirements, and the individual needs – both economic and resilient – of the sites.

The following sections will address and expand upon each of these challenge groupings in turn.

2.2 Process Issues

With the chaos that occurred during the grid outage, breakdowns in communication or training prevented pre-established black-start protocols from being implemented according to plan. In these situations, the system equipment may have functioned as designed, but communication issues, both human and digital, resulted in performance failure.

The interview team identified the following **human communication issues**:

- **Insufficient staff training:** The July 13 Con Edison power outage occurred in the evening on a summer weekend. In many cases, sites' residential managers, who were often the sole staff members to receive extensive training, were off-site when the blackout struck. As a result, these buildings were unable to implement black-start procedures on their own. The CHP operators (who typically remotely operate systems via internet connections) attempted to communicate with people on site to restart but found it challenging to explain the correct procedures to untrained staff who were not familiar with the equipment or transfer methodology. One vendor stated, "Emergencies mean that methodical approaches go out the window, especially with procedures that are usually well planned and well-trod." This highlights the fragility of resilience schemes that are based on targeted rather than widespread staff training. During this emergency in particular, taking place on a summer weekend, specially trained staff members were often unavailable, which created a communication disconnect and logistical barriers to realizing the resilience potential of these installations. In some cases, training scenarios did not accurately represent the chaos of a real power outage – anecdotally, one vendor indicated that a site had previously conducted all-hands training sessions with "a porter stationed at every switch," but they were operating with a skeleton weekend crew when the power actually went out.
- **Blackout protocol was established but not followed**: Vendors had further challenges effectively communicating with site staff due to the stressful and emotional responses that resulted from being thrust into an emergency situation without preparation. Addressing the CHP system while also dealing with an agitated response from residents caused difficulty in executing transfer steps. In the event of a grid outage such as this, the lack of preparation and prior exposure of staff to resiliency situations resulted in the inability to follow appropriate blackout protocols.
- **Inability for system operators to reach key staff at sites during the blackout**: Many sites, especially those with smaller CHP systems, do not have dedicated staff in-house to operate their CHP systems – instead, they hire outside firms (typically the CHP installer) to remotely operate installed systems. In multiple cases, the system operators had no ability to contact sites or locate key staff members to walk them through on-site issues when the grid outage occurred. As a result, they were not able to communicate with site personnel to initiate remote restarts or resets. This highlights the importance of the

relationship between operator and end user in realizing resiliency benefits in industries without an abundance of highly trained local staff, as in multifamily residence buildings.

The interview team identified the following **digital communication issues**:

- **Communications equipment did not have power:** When the grid outage occurred, internet service providers for some sites went offline and the sites were disconnected from the internet. Since all aspects of the intended communications chain were not online, remote CHP operators were severely limited in their ability to remotely operate the CHP systems. This highlights the fact that any piece of the system operation process that does not have a dedicated backup is vulnerable to failure in the event of an outage.
- **Not all black-start performance tests are true simulations of grid outages:** Throughout the industry, vendors and customers alike recognize the value in testing interconnection transfer outside of emergencies. However, many sites were hesitant to fully halt operation and shut down for "live-fire" grid outage simulation tests during normal operations. As a compromise, these sites staged simulated tests to approximate the conditions of a power outage and verify training and performance. As we determined during interviews, these simulated tests did not often accurately capture the full extent of potential challenges and power dynamics that occur during a power outage. Without a full simulation of a true outage, crucial elements of resilience system operation can go untested and fail.

2.3 Equipment Issues

Many sites experienced issues that stemmed from equipment failures that were not diagnosed or corrected prior to the blackout – we did not encounter any equipment failures directly attributable to damage caused by the outage. These issues could either prevent a system from correctly restarting or from achieving stable operation. The issues encountered and identified during the interviews are summarized here:

- **Heat rejection system failure:** When the blackout occurred, several CHP systems were able to restart as planned but quickly overheated and shut down to prevent damage to the prime movers. CHP systems are designed to recover heat from the combustion process – typically from the engine exhaust or jacket – as either hot water or steam. If that heat cannot be transferred from the heat recovery loop to another medium, either usefully applied to offset a building thermal load or rejected by the atmosphere, then heat will build up in the loop and quickly overheat the CHP engines. It appears that, in several cases, the CHP systems that were able to restart had overheated owing to failures in the systems' heat rejection systems. In several instances, pumps that circulate water through the entire heat recovery loop had failed; several vendors described VFD motors that had not been configured to automatically restart after a power outage (later corrected via firmware upgrades). In one building, the CHP system's heat rejection pump was broken prior to the outage; as the system typically operated as a thermal load-following system where heat rejection was typically unnecessary, it had not yet been replaced.

- **Essential equipment not connected to the standby load panel:** Vendors experienced difficulties remotely monitoring and operating the CHP systems during the outage. Some sites did not have critical internet connectivity equipment for the systems connected to the standby power panel, which resulted in severely limited remote functionality. There were also issues where campus-style relay protection systems had not been correctly configured or installed, which prevented the system from restarting. Simulated "black-start" tests conducted for this installation had not detected that current transformers (CTs) necessary for the relay protection schema were not installed in the correct location. This highlights the complexity and importance of each connection within these resilience schemes that can be neglected if consistent monitoring and testing is not performed.

2.4 Design Issues

System design, specifically in the amount of standby load on the system, was a surprising and consistent issue identified during operator interviews. There were fundamental problems with the way that resiliency was implemented for some systems so that, even if all processes and equipment worked properly, the system still would have failed to provide meaningful resilience. These are larger-scale issues stemming from a disconnect between the CHP program design, code requirements, and the needs of the sites. NYSERDA's program provided incentives to help end users reduce the costs associated with installing CHP systems. Any system with 50 kW or larger generating capacity was required to be installed in a black-start capable configuration; below that size range, the incentives were increased by 50% for systems that were black-start capable. The CHP program was intended to increase traction for the CHP industry in New York State but, in many cases, there were conflicts between the CHP program intent and standby power code requirements.

- **Meaningful standby loads were designed to be powered by code-required backup generators, not the CHP systems:** Many sites had installed traditional diesel-fired emergency generators in parallel with resilient CHP systems, typically as a result of code requirements. In these instances, most of the building's important standby loads were already powered by the emergency generators, as required by code. As a result, the CHP systems were left to carry "convenience" loads that were not considered important during the power outage – the CHP systems did not restart because their operation was not deemed necessary in the moment. Systems configured in this manner do not offer meaningful resiliency benefits, as the loads they are serving are not important.

- **CHP systems were not loaded above their minimum turndown setpoint:** CHP systems, as with all types of power generating equipment, are designed to be run with load. The ideal operation of a typical CHP generator will vary based on the underlying equipment, but, generally speaking, prime movers are designed to operate between 40% and 100% of their rated capacity (some CHP solution providers tout systems that can safely run to as low as 10% of the nameplate generating capacity). As with the point above, many sites that experienced this failure mode configured their standby power systems such that the CHP system was only designed to serve relatively minor convenience loads. In one instance, these loads were so minor as to fall below the associated generator's minimum operating point, forcing it to turn off. This highlights the need for careful consideration in the design phase of any standby power system, and the need for communication between the CHP designer, emergency generator vendor, and customer to deliver a system that will provide meaningful and durable resiliency.
- **Loads on the panels are "fixed":** Given code-mandated standby load requirements for some building types, meaningful electric loads are typically installed to be served by a building's existing diesel-fuel-fired emergency generator systems. However, most building types hold only a limited reserve of fuel on-site (typically 72 hours). CHP systems, on the other hand, are designed and configured to run indefinitely via pipeline natural gas – as a result, they offer longer-term resiliency than a traditional generator. Standby loads could be configured to be served by both traditional generators and CHP systems (either in parallel or with swappable loads via additional disconnects), but the vendors interviewed indicated that this almost never occurs due to increased installation costs.
- **CHP systems and typical emergency generators can't run in parallel without expensive modifications:** As noted above, choosing which power source will power which standby loads is often a one-time, fixed choice. In theory, it would be easiest and most effective if standby loads were flexibly designed to be served by CHP systems, generators, and other resilient DERs in common, pulling power from whichever source was available at any time. In practice, there are many technological challenges associated with syncing power between multiple generation sources. There are existing technologies to overcome these challenges, but to-date they are expensive and typically reserved for large, institutional microgrid installations. The vendors interviewed indicated that these technologies have not typically been employed in their target customer sectors owing to their significant expense.

3 Conclusions and Recommendations

The July 13 Con Edison electric distribution outage ultimately affected 33 DER systems that were installed through NYSERDA incentive programs. These included 28 facilities with the potential to provide energy resiliency to their host sites. ERS identified 13 CHP systems that were both configured with black-start capability and reported data of sufficient quality to NYSERDA's DERIDS website for which reliable conclusions could be drawn about their performance.

Unfortunately, although these 13 CHP systems were configured to provide priority power to their owners during grid outages, this potential was unrealized in practice. No systems lived up to the promise of DER-serviced resiliency. Only one installation performed at an acceptable level – although, even in this case, the system did not black start for nearly an hour, much longer than expected given the site's automatic transfer switch islanding system. A further two systems achieved black start but quickly shut down to prevent overheating owing to a pump failure on the heat rejection system; the system provided sufficient power to allow stranded passengers to exit elevators before shutting down.

Through interviews with the affected CHP vendors, ERS has gathered several take-away recommendations that should be addressed by the DER industry at large and by future programs to ensure that theoretical resiliency values materialize when they are needed most:

- Building operations training and real, "live-fire" blackout power tests are critical to confirm successful operation and to provide training to all participants. This is essential for manual transfer interconnection systems in particular but also presents clear value to automatic transfer switch-based installations. Resilient DER operators and customers need to work hand-in-hand to ensure that systems are able to restart safely and effectively in the event of an unexpected grid outage. One vendor interviewed confirmed that, in light of the challenges faced during this relatively benign power outage, they would implement monthly training and power outage tests with their customer sites.
- Wherever possible, DER operators and their customers should ensure that they have clear, redundant lines of communication. The system and building operators should have preexisting relationships with multiple modes of contact. Resilient DER systems should be installed to ensure that digital communications are hardened against disruption caused by localized grid outages.
- There is a conflict between code requirements for emergency generators and the ability for some DER systems to provide resiliency. At present, NYC standby load codes require that most meaningful loads are served by traditional diesel-fuel-fired emergency generators. Even if a CHP system has been installed in a building with an emergency generator, the

loads served by the CHP system are often inconsequential. DER trade associations should work with code officials to ensure that their technologies are able to offer meaningful resiliency.

- During the design phase of resilient power systems, it is critical that all potential parties – DER installers, emergency generator installers, and customers – communicate to ensure that the final standby power scheme is effective. This does represent an additional, real cost to implementing power security, but it will pay dividends by ensuring that the potential resiliency value of these systems is realized.