Hurricane Helene: Hot Springs Microgrid

Case Study

IN PARTNERSHIP WITH

DUKE ENERGY

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As electric utilities adapt to increasingly frequent and more extreme weather events and other natural disasters, resilience investments are crucial for providing reliable power, addressing changing customer demands, and supporting decarbonization strategies in an equitable and affordable manner.

For Duke Energy, the Hot Springs Microgrid project provides a blueprint for success in balancing an array of needs and challenges. After Duke Energy identified a technically and economically feasible project, obtained regulatory approval, and implemented an innovative design, the microgrid performed to provide measurable benefits during the aftermath of Hurricane Helene, one of the most severe storms to hit North Carolina. This case study explores the development, implementation, and performance of the Hot Springs Microgrid during Hurricane Helene, illustrating how innovative solutions can drive resilience, equity, and sustainability in utility operations.

Case Study Highlights

- Duke Energy initially considered traditional grid investments, such as building a second feeder or hardening infrastructure, but determined that an advanced microgrid was the most cost-effective option for improving resilience in Hot Springs. The project serves as a model for using non-traditional solutions (NTS) – such as battery-powered microgrids – to enhance reliability, particularly for areas served by a single feeder.
- The Hot Springs Microgrid features a 4.4-MW lithium-ion battery energy storage system (BESS) and a 2-MWac solar PV system, which can provide 100% of the town's peak load and up to six hours of backup power.
- Hurricane Helene's heavy rains and the subsequent flooding led to the shutdown of Duke Energy's Marshall Substation for safety. This resulted in widespread power outages that affected the entire town of Hot Springs. Without the Hot Springs Microgrid, the town would have been without power from September 27 at 11:21 AM until October 8 at

1 The authors developed this case study based on 1:1 conversations with Jason Handley at Duke Energy, a Duke Energy presentation at a public stakeholder meeting in November, and Duke Energy presentations at SEPA's December Microgrids Working Group meeting.

10:00 AM – an unmanageable **262.5 hours**.

- Duke Energy energized the Hot Springs Microgrid at 10:30 AM on October 2 and operated it continuously for the next **143.5 hours**, providing critical electricity to the town center.
- By maximizing the available power from the solar PV system and incorporating BESS, the Hot Springs Microgrid also reduced reliance on fossil fuels during the outage, minimizing emissions, reducing air pollution, and contributing to ongoing decarbonization efforts despite the natural disaster.
- While the Hot Springs Microgrid performed to provide power to the town during a historic outage, regulatory approval for Duke Energy's investment showed that the microgrid could provide benefits both to the residents of Hot Springs and to other customers; the microgrid's design was key in demonstrating these system-wide benefits.

Background

Hot Springs Context

In the remote Madison County town of Hot Springs, North Carolina, a small community sits at the end of a ten-mile power line serviced by a Duke Energy substation. Prior to the microgrid installation, its 520 residents and businesses were served by this power line with no backup power and limited rerouting options. Its remote geography makes it challenging to restore power, leading to repair delays after storms.

Duke Energy's Strategy for Reliability and Resilience Planning

To meet the resilience needs of Hot Springs, Duke Energy initially considered traditional grid investments, such as building a second feeder or hardening existing infrastructure. However, an advanced microgrid pairing solar PV and battery energy storage was identified as the most cost-effective solution. Duke Energy also consulted the town about the project, which was excited about the possibility of reducing outage minutes with an environmentally friendly solution. The Hot Springs Microgrid represents an emerging tool and technology for resilience planning – one that supports reliability while optimizing costs, community benefits, and load flexibility.

Non-Traditional Solutions (NTS) and Microgrid Investments

When considering resilience needs, Duke Energy's planning approach differentiates Non-Traditional Solutions (NTS) from conventional grid investments and distinguishes Behind-the-Meter (BTM) customer resources from Front-of-the-Meter (FTM) utility assets. Across its system, Duke Energy is considering both typical hardening options and more innovative options to build resilience. NTS, sometimes called non-wires alternatives, allow the utility to delay or avoid conventional T&D investments.

Duke Energy considers microgrids a valuable NTS tool in the energy toolbox for reliability and resilience; they are beneficial for handling increased loading in areas with changing usage patterns.

Duke Energy's current approach to reliability-driven NTS prioritizes deploying battery-powered microgrids in communities with unique geographic or service territory challenges—particularly areas served by a single, potentially vulnerable feeder line.

Resilience Investment Framework

Duke Energy balances reliability and affordability for their customers when determining which resilience solutions the utility can deploy. Duke Energy's resilience investments follow a replicable process to ensure resources are deployed effectively:

1. **Identifying reliability challenges** to focus on areas with frequent outages or chronic service challenges.
2. **Assessing geographic vulnerabilities and hazards** that consider remote, end-of-line locations or areas with recurring hazards (e.g., flooding, hurricanes).
3. **Incorporating Social Vulnerability Index metrics** to prioritize communities where outages have the greatest social and economic impact.
4. **Evaluating and comparing NTS with traditional investments** to test NTS, like microgrids, against traditional solutions for cost-effectiveness and feasibility.
5. **Establishing project guardrails** to apply specific thresholds for NTS, such as battery charging requirements, cost-effectiveness, and technical feasibility.

Regulatory Process

In order to obtain regulatory approval for the Hot Springs Microgrid, Duke Energy filed for a Certificate of Public Convenience and Necessity (CPCN) in 2017. Following a two-year regulatory review, the North Carolina Public Utilities Commission (NC PUC) approved the project in May 2019. The first-of-a-kind, in scale and structure, microgrid project began construction in 2020 and became fully operational in January 2023. Each proposed microgrid will have its own regulatory and financial considerations. Success stories like Hot Springs are laying the groundwork to demonstrate the value that these types of solutions offer to a broad array of stakeholders, including community members and regulators.

Figure 1. Hot Springs Microgrid Regulatory Process

2017	2017-2019	May 21, 2019	2020	January 2023
Duke Energy files for a Certificate of Public Convenience and Necessity (CPCN) with the North Carolina Public Utilities Commission (NC PUC).	Regulatory review process takes place over two years.	NC PUC approves the project, citing customer benefits, cost protections, and grid reliability improvements.	Construction begins on the Hot Springs Microgrid.	Microgrid becomes fully operational.

Duke Energy and other utilities can apply the lessons learned and best practices from the Hot Springs microgrid to other projects to facilitate regulatory approval and stakeholder collaboration, as well as implement technical and financial innovations. In particular, Duke Energy demonstrated that the Hot Springs Microgrid's design would benefit the town and other customers, which can be key for regulatory approval and cost recovery. As noted by the NC PUC in the approval order on May 21, 2019:

"The Commission finds and concludes that these reporting requirements, cost cap, and conditions, negotiated and agreed to by Duke Energy Progress [DEP] and the Public Staff, are appropriate and provide additional protections to ensure that all of DEP's customers will benefit from the deployment of the Hot Springs Microgrid. In addition to providing renewable generation to the DEP grid, while grid-tied, the Hot Springs Microgrid will be capable of providing additional bulk system benefits for all of DEP's customers, including reliability services to the DEP electric grid, such as frequency and voltage regulation and ramping support, and capacity during system peaks."

- North Carolina Public Utility Commission, May 21, 2019
Read the full NC PUC Order here

Microgrid Overview

The advanced microgrid consists of a 4.4-MW lithium-ion battery energy storage system (BESS) capable of meeting 100% of the town's peak load and providing 4-6 hours of backup power. It can also generate electricity to meet additional demands from its 2 MWac solar PV system. The microgrid is designed as a front-of-the-meter (FTM) resource, meaning the assets are owned and operated by Duke Energy, which can choose to operate it in grid parallel mode[2] or independently from the grid during a grid outage to provide reliable power for residents.

Instead of building miles of power lines and traditional infrastructure, Duke Energy located solar arrays, battery storage, and distributed generation in the town of Hot Springs to deliver reliable, resilient, and sustainable power.

Source: Duke Energy, 2024

2 The Hot Springs Microgrid operates primarily in grid parallel mode during normal grid operations and only islands during emergency operations when the larger grid is down.

Community Hubs vs. Utility Microgrids

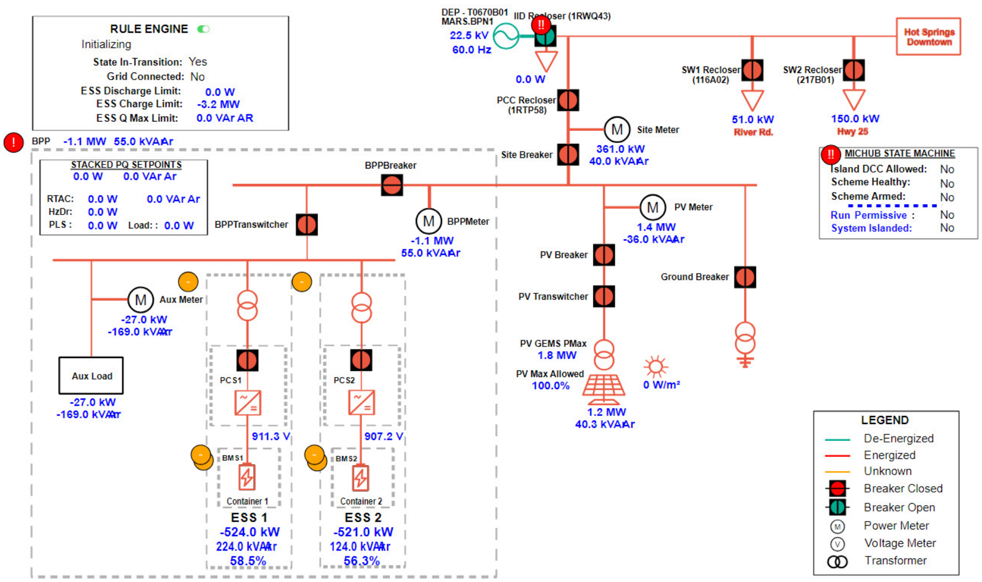
The term "microgrid" can often be conflated with smaller, BTM solutions like "community hubs" or "nanogrids." While both contribute to resilience, they serve distinct purposes:

- **Community or Resilience Hubs (Nanogrids):** Site-specific solar PV + battery energy storage systems (BESS) designed for critical facilities, such as community centers. These provide temporary, localized backup power, but do not serve an entire community.
- **Utility Microgrids (FTM):** Grid-scale solutions, like the Hot Springs Microgrid, that integrate DERs at scale to serve entire communities, dynamically balance load, and support critical infrastructure during prolonged outages.

While community hub projects (e.g., battery energy storage + solar PV at critical facilities) play a complementary role, larger utility-operated microgrids deliver wider-reaching resilience benefits by mitigating widespread outages and protecting essential services.

The microgrid schematic below provides a single-line diagram of the system which includes the energy storage units, solar panels, inverters, and balance of plant equipment. It also highlights the main switches in the microgrid that allow Duke Energy to provide both grid parallel and islanding services to the town through the Intentional Islanding Recloser (1RWQ43), the Point of Common Coupling Recloser (1RTP58), and the two load segment reclosers (116A02 and 217B01). This single-line diagram allows the microgrid operators to have real-time status and information about the microgrid, including loads, breaker status, state of charge of the batteries, and solar output.

Figure 2. Hot Springs Microgrid Schematic



This schematic shows the solar producing 1.2MW, serving the customer load of 361kW and then sending the rest of the solar output to charge the batteries.

Source: Duke Energy, 2024

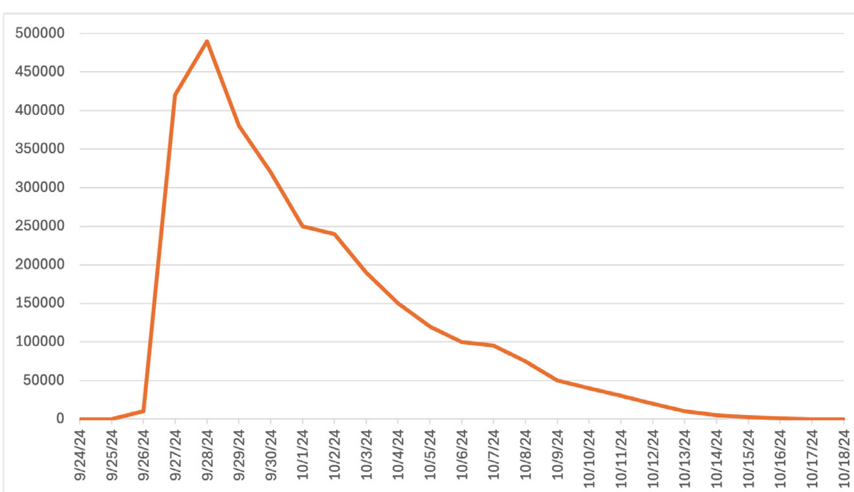
Duke Energy chose to pursue an inverter-only microgrid design in Hot Springs for several reasons, including this project's location. The inverter-only based design – without any fossil-based generating backup, is more environmentally friendly in the mountains of Western North Carolina, where customers are sensitive to these issues. In addition, this design allows for reduced mechanical complexity because the generation backup, which involves rotating machinery which can break and contribute to noise levels, was not used. Finally, the total ownership costs for operations and maintenance of this microgrid will be reduced due to having no fuel costs, which will be another benefit for customers. Future designs may incorporate a backup generator if the use case, environmental criteria, and costs indicate that it would enhance a project's design.
The Hot Springs inverter-only based design has been the model that Duke Energy has used for its other six front-of-the-meter (FTM) microgrids in service or under construction at this time. Lessons learned on interconnection, relaying, and automation schemes have all been applied to other projects, demonstrating that they are scalable and repeatable.

Hurricane Helene: Microgrid Performance

The Hot Springs Microgrid was put to the test during Hurricane Helene, demonstrating its ability to provide critical backup power when severe flooding and infrastructure failures caused widespread outages. The following timeline details the microgrid's performance and Duke Energy's response efforts during the storm.

- **September 25th to September 27th, 2024:** Hurricane Helene struck, dropping 14 inches of rain, causing flash flooding, landslides, and road closures. The rising waters of the French Broad River forced Duke Energy to shut down the Marshall Substation for safety reasons, cutting power to many customers, including the entire town of Hot Springs.

Figure 3. Duke Energy customers without power over time in North Carolina from September 25th to October 17th, 2024



Source: Find Energy, 2024

[Watch drone footage of the conditions in Hot Springs, North Carolina, following Hurricane Helene.]

- **September 30th, 2024:** Duke Energy coordinated with local officials, including the town mayor and the North Carolina Department of Transportation, to gain access and initiate restoration efforts. Communication with the town was critical—Duke Energy worked with the mayor to share updates via social media when limited telecommunications came back online, keeping residents informed during the crisis.

Impacts to Marshall Substation during Hurricane Helene

Source: Duke Energy, 2024

- **October 2nd to October 8th, 2024:** From October 2nd at 10:30 am to October 8th at 10:00 am, the microgrid began delivering power to critical services in downtown Hot Springs on October 2nd at 10:30 AM. The advanced system—consisting of a BESS and solar panels—enabled Duke Energy to manage power dynamically during the outage, serving the main downtown section of the microgrid, which included critical facilities such as the fire station, gas station, Dollar General, and Smoky Mountain Diner. Load management was used for two circuit sections, supplying energy for over 12 hours each day to support critical needs.
- **October 4th, 2024:** The microgrid faced heavy cloud cover and rain, reducing solar generation significantly. Despite this, Duke Energy managed the load carefully, prioritizing essential areas and minimizing disruptions. Due to the microgrid circuit layout in the town, Duke Energy had to keep the downtown area energized and manage the load with the two reclosers. The microgrid's BESS played a major role in maintaining a stable power supply during the outage.

Additional findings from this event highlight the broader impact of Duke Energy's microgrid management strategy. Assuming standard fuel efficiency and emission factors, a traditional solution, such as a 2MW diesel generator with a 50% load factor running for 143.5 hours, would have emitted approximately 153.8 metric tons of CO_2 and significant amounts of other air pollution. The microgrid's ability to provide power without relying on fossil fuels underscored its environmental benefits.

Duke Energy's proactive communication efforts were essential in keeping the town informed throughout the crisis. Regular updates were shared with the Mayor and posted on social media, ensuring residents understood how the microgrid's typical capability of 4-6 hours of continuous power was being extended through strategic load reductions due to flooding impacts. By actively managing the load each night, Duke Energy could stretch power availability while implementing temporary overnight outages to conserve energy.

Read testimonials from residents who provided comments in Duke Energy's Illumination story: How new technology is keeping the lights on in NC mountain town | Duke Energy | illumination

Lessons Learned

In collaboration with Duke Energy, SEPA developed key takeaways from the Hot Springs microgrid's performance during Hurricane Helene. While the microgrid successfully mitigated many of the storm's impacts, it also revealed valuable opportunities for improvement. This section highlights the lessons learned and outlines the next steps for refining microgrid operations and resilience strategies.

- **Increasing solar capacity** can help mitigate reduced output in adverse weather that produces limited solar generation.
- **Conducting proactive maintenance** of battery systems helps ensure their reliability during emergencies. To address the issue of auxiliary battery depletion during prolonged grid repairs, Duke Energy is installing a small generator to support all auxiliary loads, extending backup capability beyond the current 6–12-hour battery limitation.
- **Improving community engagement and communication** can help manage expectations and ensure smooth operations.
- **Exploring added value** through avoided outage costs, business continuity, and customer satisfaction can further highlight the benefits of future microgrid projects.
- **Gathering additional feedback** from the Hot Springs community can help refine future microgrid operations and resilience strategies.
- **Demonstrating the quantitative benefits** of resilience investments, such as avoided outage costs, metrics around improved public safety, and customer satisfaction, can facilitate improvements and scalability.
- **Scaling the model** across their service territory by replicating their planning approach can help identify more communities that could benefit from non-traditional resilience solutions.

Broader Implications for Utilities and States Across the U.S.

The Hot Springs use case provides a roadmap for deploying non-traditional solutions, like batteries and microgrids, in other areas across the country that have similar attributes to Hot Springs:

- **Remote, end-of-line communities** at the end of radial power lines or in geographically isolated locations.
- **Capacity-constrained areas** where upgrading the distribution and/or transmission infrastructure may be cost-prohibitive.
- **Hazard-prone zones** where communities are vulnerable to recurring natural disasters.
- **Aging Infrastructure** where there are potentially cost-effective alternatives to evaluate.

Duke Energy's approach of identifying reliability and resilience investments, obtaining regulatory approval, and demonstrating customer benefits offers a replicable framework for developing tools for climate adaptation, disaster readiness, and bulk system reliability and capacity benefits.

A Blueprint for Resilience

The Hot Springs Microgrid exemplifies how utilities can successfully navigate resilience challenges through innovative solutions. By aligning technical rigor with social and geographic vulnerability considerations, Duke Energy has created a scalable model for identifying future resilience investments and evolving use cases for non-traditional solutions like microgrids. The project highlights the importance of these non-traditional solutions in enhancing reliability, driving decarbonization, and protecting communities that are likely to experience power outages during extreme events. Looking into the future, we can expect similar projects to be added to the utility pipelines to alleviate the reliability or resilience needs of communities impacted by extreme weather.

Curious about SEPA's resilience resources?

Dive into our research knowledge center and learn about SEPA's Microgrids Working Group!

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