ENERGY GRID RESILIENCE AND MICROGRIDS

Slide Presentation

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Course content based on the Energy Grids panel at the

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Energy Grid Resilience & Microgrids

Understanding how power systems can adapt to extreme weather events

Author: Bianca Meotti

The Problem: Power Outages & Extreme Weather

- Extreme weather events are becoming more frequent and severe across the U.S.
- Hurricane Helene (Sept. 27, 2024) devastated Western NC: widespread flooding, downed lines, isolated communities.
- The Western Appalachian region lost power, water, and cellular communications simultaneously.
- Roads were washed out: communities became cut off; hospitals flooded.
- People with medical equipment had no power and no access to fuel for generators.

WEEKS

Power out in some WNC areas

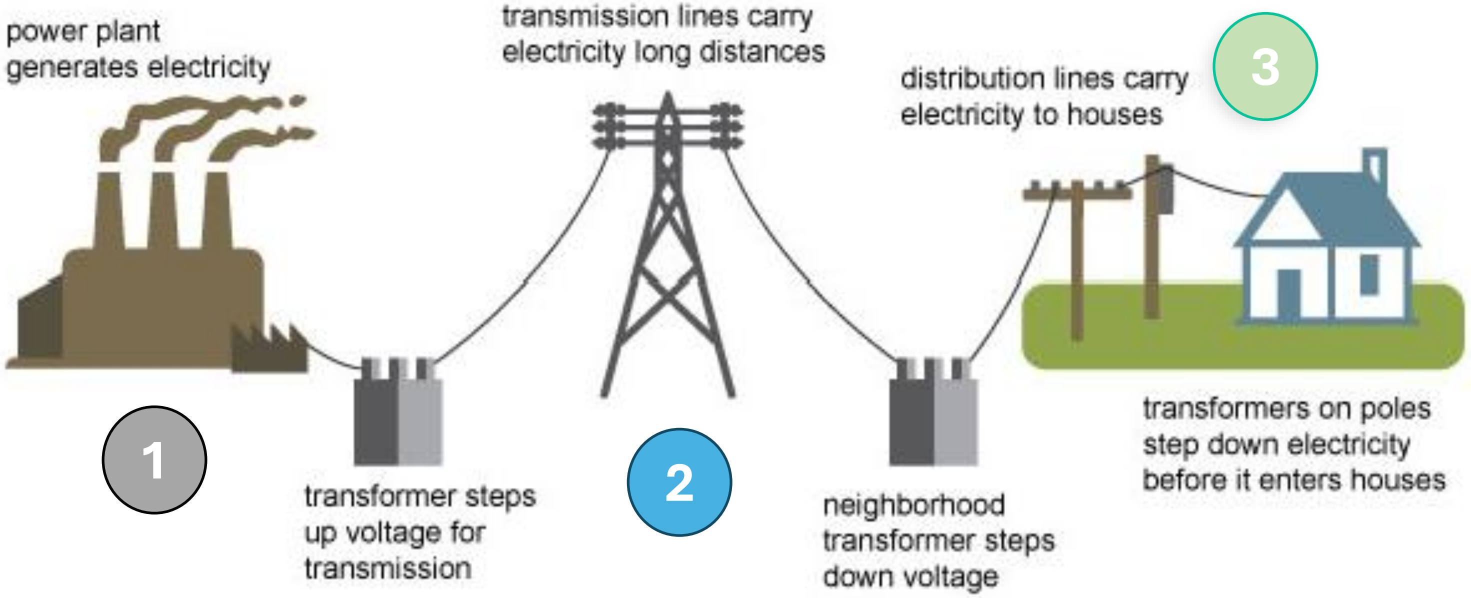
DAYS

Cell towers & internet down

MILES

Roads damaged or destroyed

How the Electric Grid Works



Source: Adapted from National Energy Education Development Project (public domain)

1 Generation

Large power plants (coal, gas, nuclear, solar, wind) produce electricity at high voltage

→

2 Transmission

High-voltage lines carry power long distances across states and regions

→

3 Distribution

Lower-voltage local lines deliver power to homes, schools, and businesses, where MOST outages happen

How the Electric Grid Works

Most outages occur at the distribution level: from trees, vehicle accidents, or equipment failure.

Aftermath of hurricane Helene in Waycross, GA

Aftermath of hurricane Helene in South Carolina

What Is a Microgrid?

A microgrid is a local energy system that can supply power to a specific area, either connected to the main grid or operating independently (islanding) during an outage. Most common microgrid structure: solar panels + battery storage.

Connected to the Grid (Normal Days)

- Solar charges the battery during the day
- Excess energy can be exported to the main grid
- Battery discharges during early morning peak demand — offsetting fuel costs
- Can provide frequency regulation services to stabilize the broader grid

Islanding Mode (During Outage)

- When the main grid goes down, the microgrid disconnects automatically
- Batteries and solar supply power to the local community
- Cold load pickup: surge when power returns, then settles to normal load
- Can sustain a community for 4–8+ hours depending on system size and demand

Islanding a Microgrid – NREL

Case of Hot Springs, NC Microgrid

Hot Springs is a small town in Western NC served by a 10-mile distribution line through rugged, steep terrain. It is prone to prolonged outages caused by storms and fallen trees.

- 2 MW solar array + 4.4 MW / 4.4 MWh battery energy storage
- When an outage occurs: microgrid disconnects from Duke's grid and powers the town independently
- Has provided backup power for up to 7–8 hours during extended outages
- Charges battery via solar during the day; discharges 1 MW during early-morning peak hours
- A non-wires alternative: deferred a costly traditional line upgrade
- Approved through the state regulatory process (CPCN). Required to demonstrate public need and cost-effectiveness

Benefits of Microgrids

Reliability & Resilience

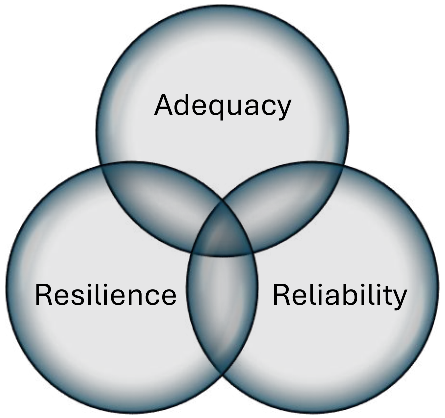
- Keeps power on during grid outages: important for remote and isolated communities
- Reduces outage duration and frequency (improves SAIDI & SAIFI metrics)

  SAIDI measures how long outages last
  SAIFI measures how often outages happen

- Enables islanding: local power even when the main grid is completely down
- Can sustain hospitals, emergency shelters, and critical facilities for hours
- Provides backup for people relying on medical equipment at home

Environmental & Economic

- Reduces reliance on noisy, polluting diesel generators during disasters
- Integrates renewable solar energy directly into local infrastructure
- On normal days: battery can generate revenue via frequency regulation
- Delays or avoids expensive grid upgrades
- Supports NC's clean energy goals and reduces grid carbon emissions



Challenges & Limitations

Cost & Economics

- High upfront capital cost. Example: Hot Springs microgrid: ~$15M final cost
- Final cost usually higher than initial cost projections due to many unpredictable variables.
  - Example: Initial estimate for Hot Springs was $11.4M. Cost grew 30%+ due to COVID delays and inflation
- Benefit-cost ratio near break-even (~0.97): benefits barely outweigh costs
- Microgrid projects cost 60–75% more per kW/kWh than utility-scale grid storage
- Projected benefits often don't fully materialize

Technical & Regulatory

- Connecting microgrids to the grid is time-consuming and requires extensive regulatory approval
- Microgrids need more advanced protection systems to detect and respond to faults
- Grid limitations can prevent microgrids from using their full capacity
- Expected financial benefits may not materialize due to technical limitations
- Difficult to measure the value of resilience in economic terms

Disaster Response after Hurricane Helene

How solar + battery technology helped real communities during Hurricane Helene

Disaster Response: By the Numbers

Western NC response following Hurricane Helene in October 2024

97

Requests for power assistance received

49

Sites supported with clean energy

100+ kW

Solar PV deployed across region

250+ kWh

Battery storage deployed in the field

Disaster Response: Community Impact

Sites ranged from community hubs to individual homes with medical equipment needs

2,000+	$1M+	~60
People served per day across all active sites	Value of clean tech assets deployed	Sites still active one year later (camper residents)

Disaster Response: Clean Energy After Hurricane Helene

- Mobile solar + battery systems were rapidly deployed to communities cut off from the grid
- Traditional diesel generators required constant refueling — impossible in flood-damaged, road-less areas
- Clean energy technology deployed across Western NC:
  - Mobile solar trailers with built-in PV, battery storage, refrigeration, and satellite internet
  - Ground-mount solar arrays at community hubs (e.g., Marshall, Barnardsville)
  - Portable battery units
- People with home health needs (oxygen, CPAP) could stop running noisy generators at night for the first time
- Solar + battery proved quieter, cleaner, and more reliable in isolated areas than diesel alternatives

Equity & Policy Considerations

Who Pays?

Microgrids are funded by all ratepayers, regardless of who directly benefits.

Who Benefits?

Reliability and resilience benefits are localized to the community served.

The Gap

Residential customers may pay 50% of costs but receive only 15% of quantified benefits.

Vulnerable Communities

Low-income and rural areas often have the worst reliability but the least power to advocate for investment.

Possible Solution

Grant-funded, behind-the-meter microgrids can reduce cost-sharing inequities.

The Question

How can we design resilience investments that are cost-effective and equitably distributed?

Future of Microgrids in North Carolina

24

Sites to receive solar + battery microgrids

500+ kW

Solar PV to be installed across WNC counties

1+ MWh

Battery storage to be installed

200+

People trained on installation & maintenance

Target counties: Avery, Buncombe, Madison, Mitchell, Rutherford & Yancey

- $5M NC DEQ Grant Program to install up to 24 stationary microgrids for resilience hubs.
- Two mobile 'Beehive' hubs to be deployed: one in Western NC, one in Eastern NC.
- Behind-the-meter design: no complex grid interconnection agreements required.
- Pilot program designed to attract future funding and expand statewide.
- Ongoing workforce training ensures communities can maintain their own systems.

What is a Beehive?

DEFINITION

A mobile clean-energy hub that deploys portable microgrids ("bees") to communities during emergencies. Provides flexible, off-grid power during disruptions.

THE HIVE

Central energy + storage base

Stationary hub

Fixed solar array & large battery bank

Energy reservoir

Stores and distributes energy to mobile units (“bees”)

Logistics center

Packs up, loads on trucks, moves to the next disaster zone

THE BEES

Mobile trailers

Mobile solar + battery units

Deployed for disaster response and community support

Deploy during outages

Serve community hubs, response sites

Return & recharge

Cycles back to hive when mission is done

WHAT IT PROVIDES

Life-critical services during disasters

Health & medical

Powers oxygen, CPAP, medication refrigeration

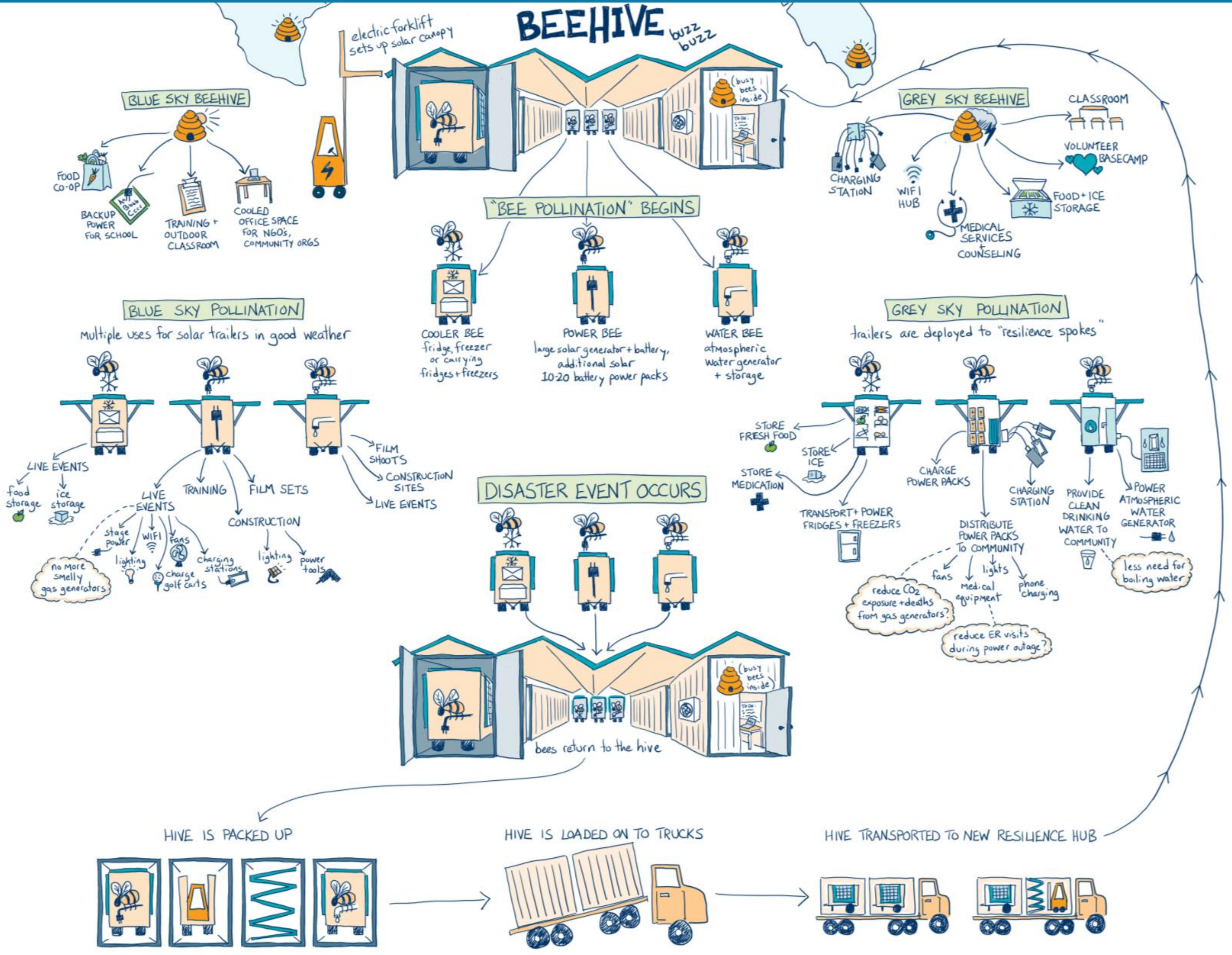
Communications

Satellite internet, device charging, recovery services

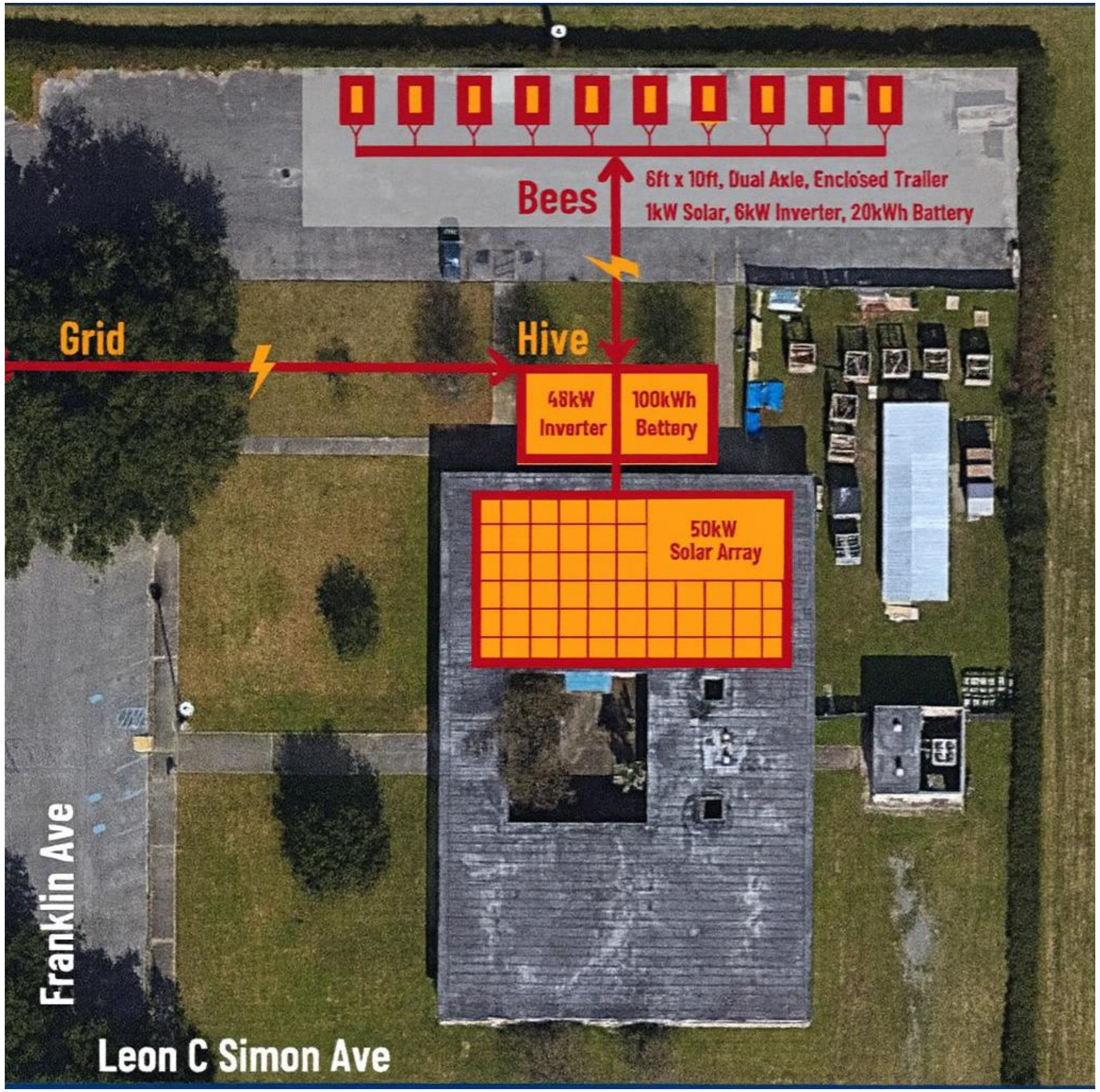
Clean alternative

Replaces noisy, polluting diesel generators

Beehive Overview

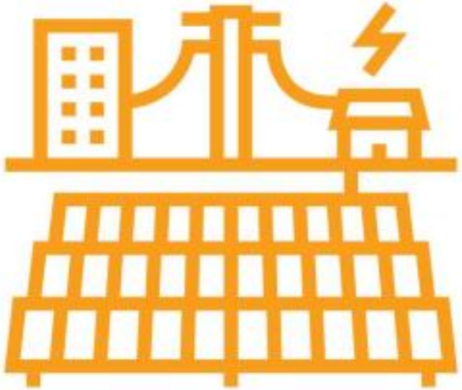


Beehive Layout



BEES

HIVES



Takeaways

- → Extreme weather is increasing: investing in grid resilience is urgent.
- → Microgrids can keep communities powered during grid outages.
- → Building and operating a microgrid is complex: real-world performance often differs from projections.
- → Cost-benefit distribution raise real equity questions: who pays vs. who benefits matters.
- → Effective solutions require collaboration across government, utilities, nonprofits, and communities.
- → Clean energy disaster response reduces reliance on fossil fuels and strengthens community resilience.

Discussion Questions

1. Where should microgrids be prioritized: largest populations or most vulnerable communities? How would you decide?

2. A microgrid serving a small town costs ~$15 million and is funded by all state ratepayers. Is this equitable? How would you design a fairer policy?

3. What are the trade-offs between solar + battery systems and diesel generators during disasters? When would you choose one over the other?

4. How can we quantify the value of resilience — the benefit of NOT losing power — in dollar terms?

5. What role should state government, utilities, nonprofits, and local communities play in funding resilience infrastructure?

About the Author

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About This Work

This presentation was developed as part of an initiative to create **curricular materials** based on real-world case studies for use in college courses and K-12 classroom, funded by NC State's Sustainability Fund.

The content is based on the Energy Panel presented at the 2025 Fall Symposium as part of the KIETS Climate Leaders Program. The goal is to bridge real-world energy resilience challenges with academic coursework, providing students across disciplines with practical knowledge about microgrids and grid resilience.

"Resilience, equity, and innovation must guide future energy systems."