ENERGY GRID RESILIENCE AND MICROGRIDS

Teaching Notes

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Teaching Note: Energy Grid Resilience & Microgrids

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1. Case Summary

This teaching module examines the role of microgrids in enhancing energy resilience in the context of increasing extreme weather events. Using real-world examples, including the Hot Springs, North Carolina microgrid and disaster response efforts following Hurricane Helene, the case illustrates how decentralized energy systems can provide reliable, localized power during grid disruptions.

The case highlights both the technical and societal dimensions of microgrid deployment. It explores system operation, performance under real-world conditions, and the trade-offs associated with cost, scalability, and implementation complexity. In addition, the module introduces the “beehive” concept, which is a mobile, distributed clean-energy response system designed to rapidly deploy power to isolated communities during emergencies.

Beyond technical considerations, the case emphasizes equity and policy challenges, particularly the mismatch between who pays for resilience infrastructure and who benefits from it. Students are encouraged to critically evaluate how resilience investments can be designed to balance efficiency, cost-effectiveness, and equitable outcomes.

2. Teaching Objectives

- Understand how the electric grid functions and why outages occur.
- Explain microgrid operation, including islanding.
- Evaluate the benefits and limitations of microgrids for resilience.
- Analyze real-world applications (e.g., Hot Springs, NC; Hurricane Helene).
- Assess equity and policy challenges in resilience investments.
- Discuss trade-offs between technical feasibility, cost, and social impact.

3. Target Audience

This module is designed for upper-level high school students and undergraduate students across multiple disciplines, including engineering, environmental science, public policy, sustainability, and energy systems. It is particularly suitable for courses such as:

- Energy Systems or Power Systems
- Environmental Engineering or Environmental Science
- Climate Change and Sustainability

- Public Policy or Energy Policy
- Infrastructure Systems or Resilience Planning

The interdisciplinary nature of the material makes it appropriate for both technical and non-technical audiences. For engineering-focused courses, the module supports understanding of system design and operation, while for policy-oriented courses, it facilitates discussion of governance, equity, and decision-making in infrastructure investment.

4. Suggested Teaching Strategy

This module is designed to promote active learning through a combination of structured content delivery, real-world case analysis, and guided discussion.

The session should begin with a brief introduction to the problem of increasing extreme weather and its impacts on energy infrastructure (Slides 1–2), establishing the real-world relevance of the topic. Instructors should emphasize the concept of cascading failures (e.g., simultaneous loss of power, water, and communication systems).

Next, foundational knowledge should be introduced (Slides 3–6), including how the electric grid operates and how microgrids function, with particular attention to the concept of islanding. At this stage, instructors are encouraged to use visual aids and short videos (e.g., the NREL islanding example) to support comprehension.

The case study (Slide 7) should be used to transition from theory to application. Instructors should guide students to evaluate the Hot Springs microgrid not only in terms of technical performance but also in terms of cost, feasibility, and infrastructure trade-offs (e.g., non-wires alternatives).

Following this, the discussion of benefits and challenges (Slides 8–9) should be structured as a guided comparison. Students can be prompted to identify key trade-offs, such as reliability versus cost, or innovation versus uncertainty.

The disaster response section (Slides 10–13) should be presented as a real-world validation of microgrid applications. Instructors should emphasize the advantages of solar + battery systems in constrained environments (e.g., lack of fuel access), as well as their role in supporting critical services such as healthcare and communication.

The equity and policy discussion (Slide 14) should be highly interactive. Instructors are encouraged to engage students in small-group discussions or think–pair–share activities to explore questions related to cost allocation, vulnerable communities, and fairness in infrastructure investment.

The final section (Slides 15–18) introduces future directions and the "beehive" concept. This provides an opportunity to discuss innovation, scalability, and system design in emerging energy solutions.

The session should conclude with a synthesis of key takeaways (Slide 19) and a structured discussion (Slide 20), encouraging students to integrate technical, economic, and social perspectives.

5. Session Structure (50–60 minutes)

- Introduction & Problem (Slides 1–2): 5 min
- Grid Basics (Slides 3–4): 5 min
- Microgrids (Slides 5–6): 5 min
- Case Study (Slide 7): 5 min
- Benefits & Challenges (Slides 8–9): 7 min
- Disaster Response (Slides 10–13): 5 min
- Equity & Policy (Slide 14): 5 min
- Future + Beehive Concept (Slides 15–18): 8 min
- Takeaways (Slide 19): 2 min
- Discussion (Slide 20): 5–10 min

6. Key Concepts

- Resilience vs. reliability
- Centralized vs. decentralized systems
- Non-wires alternatives
- Equity in infrastructure investment
- Trade-offs in decision-making

7. Discussion Guidance

- Location decisions: efficiency vs. equity
- Cost fairness: public vs. private benefit
- Technology trade-offs: reliability vs. sustainability
- Valuation: challenges in quantifying resilience
- Governance: multi-stakeholder coordination

8. Assessment Ideas

- Short reflection question
- Group prioritization activity
- Assignment

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