Bonus Module: Using Solar for Resilience

Eliza Hotchkiss, NREL

City and County Solar PV Training Program

Trainings

Module 1:
Develop your goals and team

Module 2:
Identify Sites and Screen

Module 3:
Complete Detailed Site Evaluation

Module 4:
Decide on a Financial Model and Use all Available Incentives

Module 5:
Issue a request-for-proposals

Learning Objectives

- Understand how resilience is being used for this training module
- Understand the importance of energy resilience
- Understand how PV systems can be designed to enhance resilience
- Understand where solar PV is being used for resilience currently

Defining Resilience

Resilience Overview

Energy Resilience

Solar PV + Resilience

Best Practices

How is resilience defined?

Executive Order 13653 "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions".

Presidential Policy Directive 21 "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents"

DOE's Office of Electricity "the ability of an energy facility to recover quickly from damage to any of its components or to any of the external systems on which it depends".

Rockefeller Foundation's 100 Resilient Cities "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience."

The Colorado Recovery and Resilience Office "the ability of communities to rebound, positively adapt to, or thrive amidst changing conditions or challenges ... and maintain quality of life, healthy growth, durable systems, economic vitality, and conservation of resources for present and future generations."

The National Institute of Standards and Technology has a **number** of definitions for resilience in their Community Resilience Planning Guide resulting from a series of stakeholder group meetings.

How is resilience defined?

WHAT IS RESILIENCE?

The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through adaptable and holistic planning and technical solutions.

Resilience Overview

Goal setting is essential!

BOULDER'S APPROACH TO RESILIENCE

CITY RESILIENCE FRAMEWORK

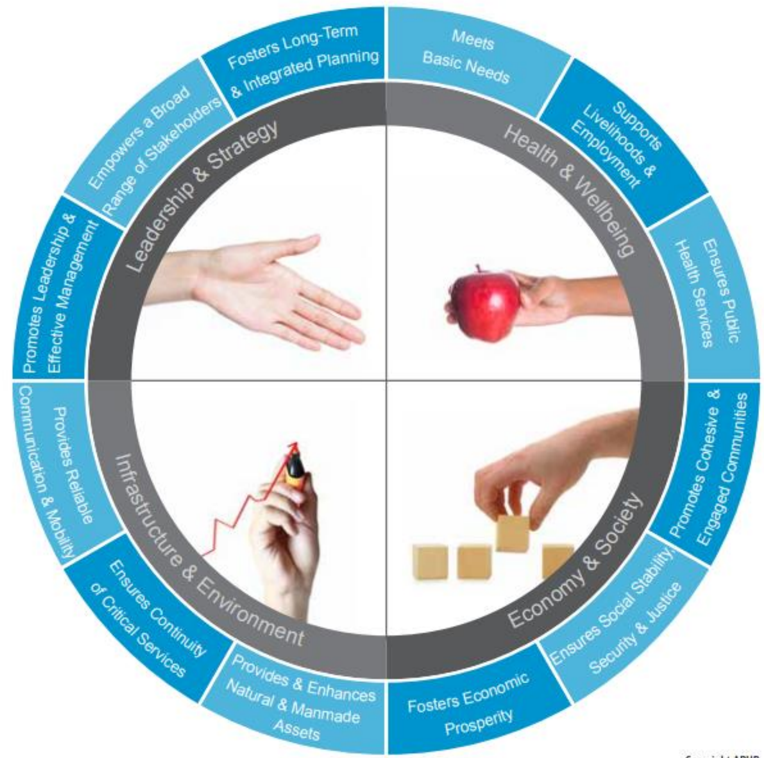
The City Resilience Framework (CRF) provides a lens to understand the complexity of cities and the drivers that contribute to their resilience, and a common language that enables cities to share knowledge and experiences. The framework is built on four essential dimensions of urban resilience: Leadership & Strategy, Health & Wellbeing, Economy & Society, and Infrastructure & Environment. Each dimension contains three "drivers," which reflect the actions cities can take to improve their resilience.

Leadership & Strategy
The processes that promote effective leadership, inclusive decision-making, empowered stakeholders and integrated planning.

Health & Wellbeing
Everyone living and working in the city has access to what they need to survive and thrive.

Economy & Society
The social and financial systems that enable urban populations to live peacefully and act collectively.

Infrastructure & Environment
The physical and natural systems that provide critical services and protect and connect urban assets, enabling the flow of goods, services and knowledge.



[City of Boulder's Resilience Strategy](https://www-static.bouldercolorado.gov/docs/Resilience_Strategy_Final_Low-Res-1-201701120822.pdf?_ga=2.7587698.1389186300.1519480717-616319713.1519480717)
https://www-static.bouldercolorado.gov/docs/Resilience_Strategy_Final_Low-Res-1-201701120822.pdf?_ga=2.7587698.1389186300.1519480717-616319713.1519480717

Resilience Overview

Potential Impacts

+

Probability of Occurrence

Risk Assessment Matrix:

Impact x Probability

Likelihood \ Impact	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Ranking of Threats and Vulnerabilities

High, Medium, Low

Resilience Options Evaluation:

Cost, effectiveness, feasibility

Resilience Strategies

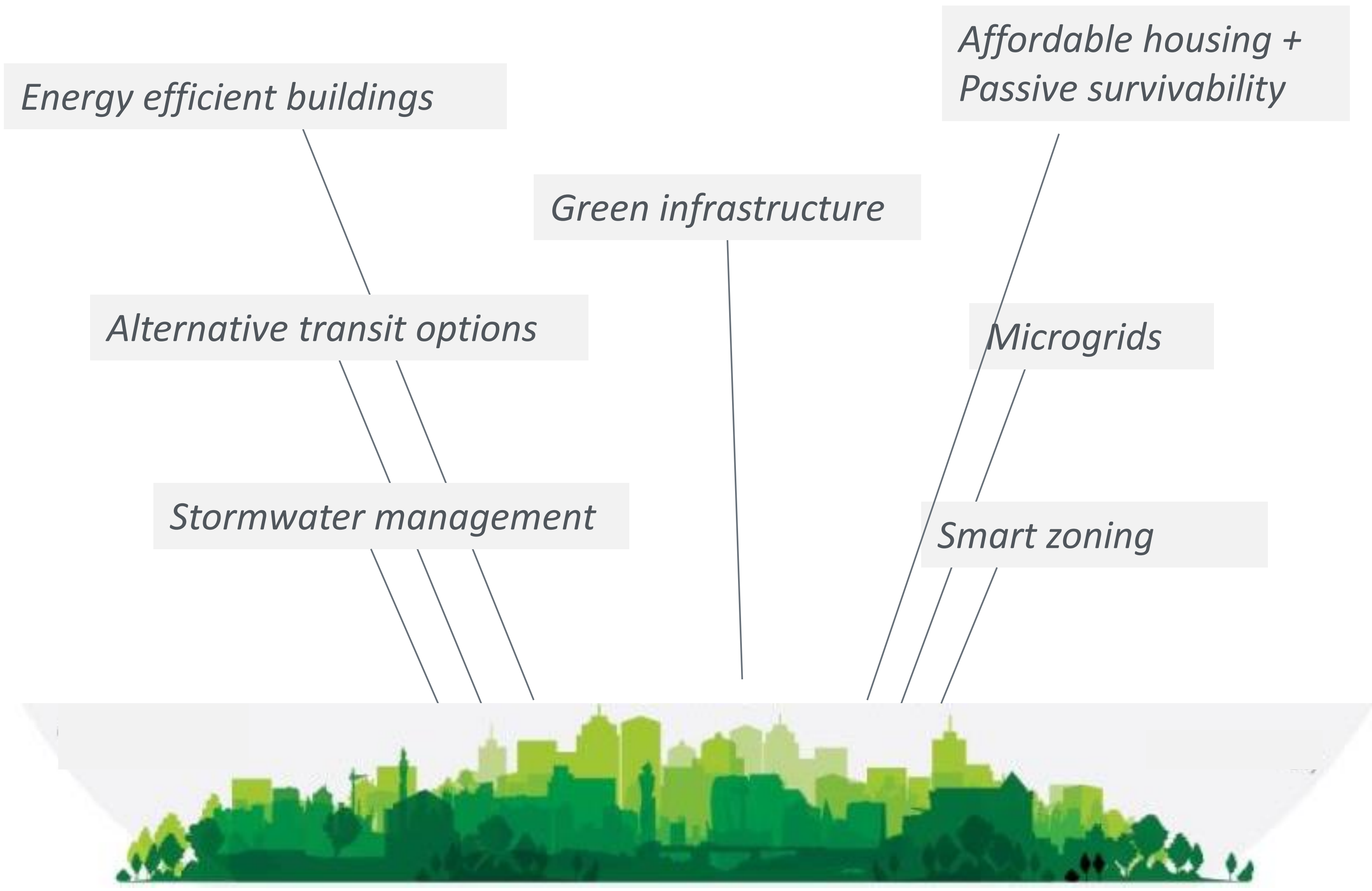
Resilience Overview

Goal setting is led by first understanding risks through an assessment of threats, vulnerabilities, and then discussing mitigation options. In order to establish goals a city needs to know what's being addressed.

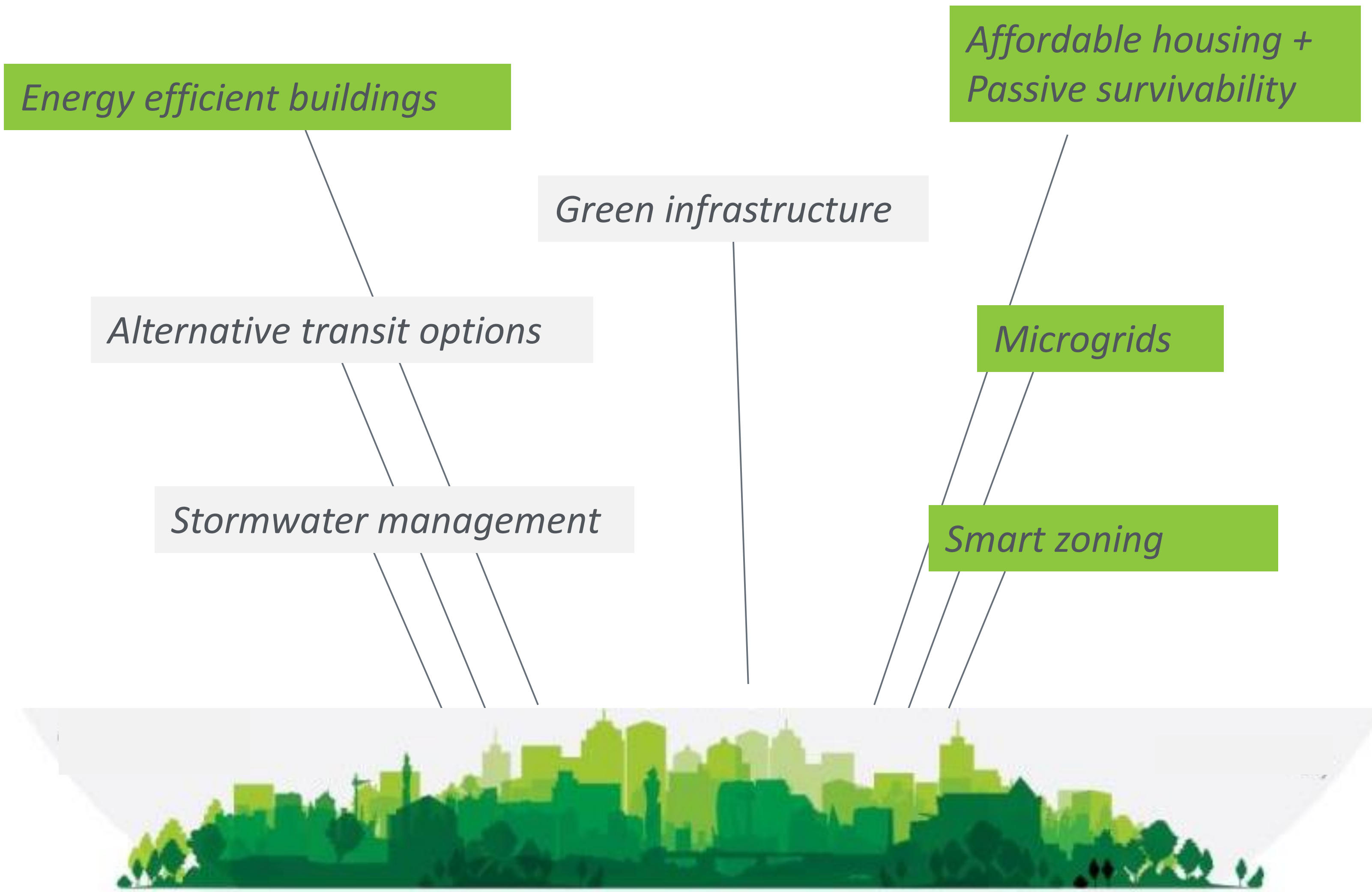
"What are we planning to become resilient to and for how long?"

Graphic source: City of Boulder's Resilience Strategy

Resilience Overview



Resilience Overview



Defining Resilience

Resilience Overview

Energy Resilience

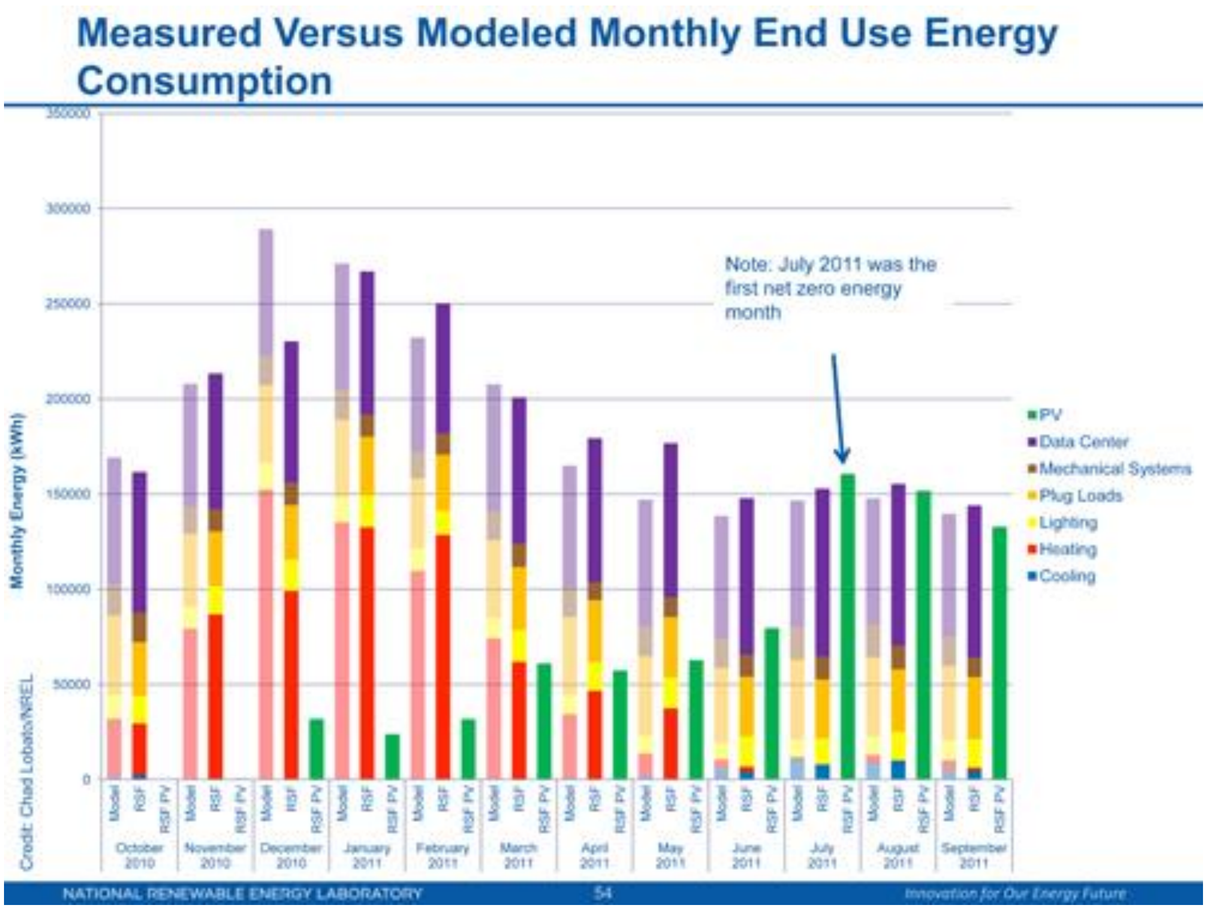
Solar PV + Resilience

Best Practices

Energy Resilience

A key piece to energy resilience is understanding energy needs.

1) Understand load profiles and critical loads



Energy Resilience

A key piece to energy resilience is understanding energy needs.

2) Understand generation, transmission and distribution

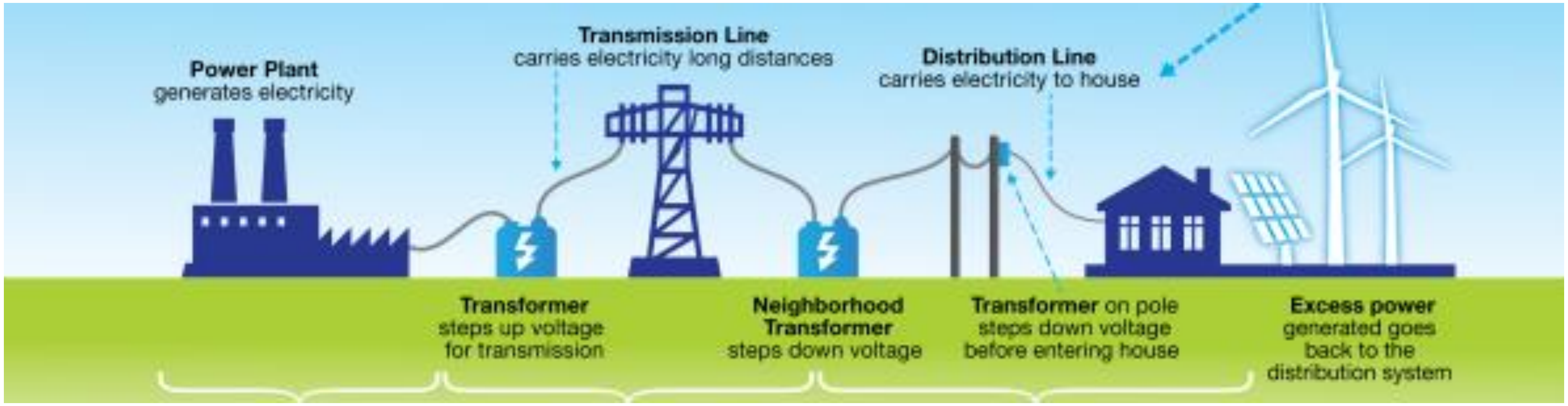


Image source: www.whatissmartgrid.org/smart-grid-101/fact-sheets/what-distributed-generation-and-net-metering-mean-for-you

Energy Resilience

A key piece to energy resilience is understanding energy needs.

3) Understand common causes of energy disruptions

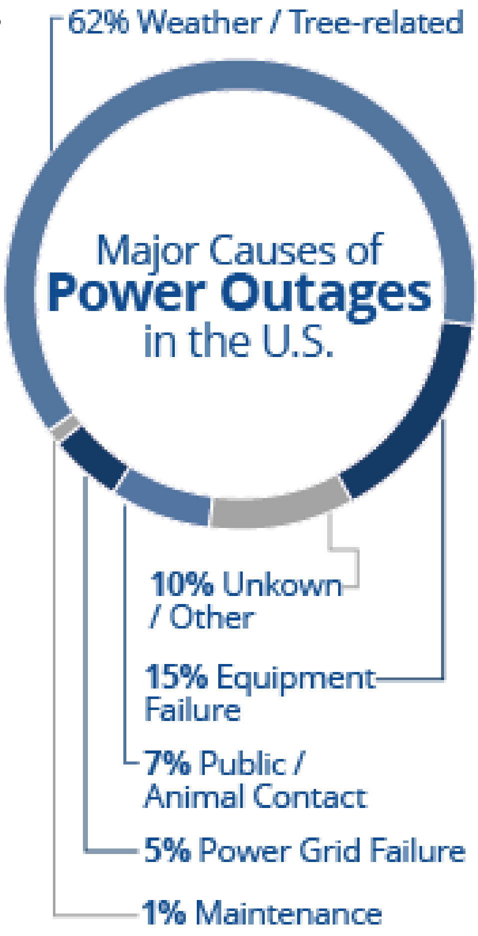
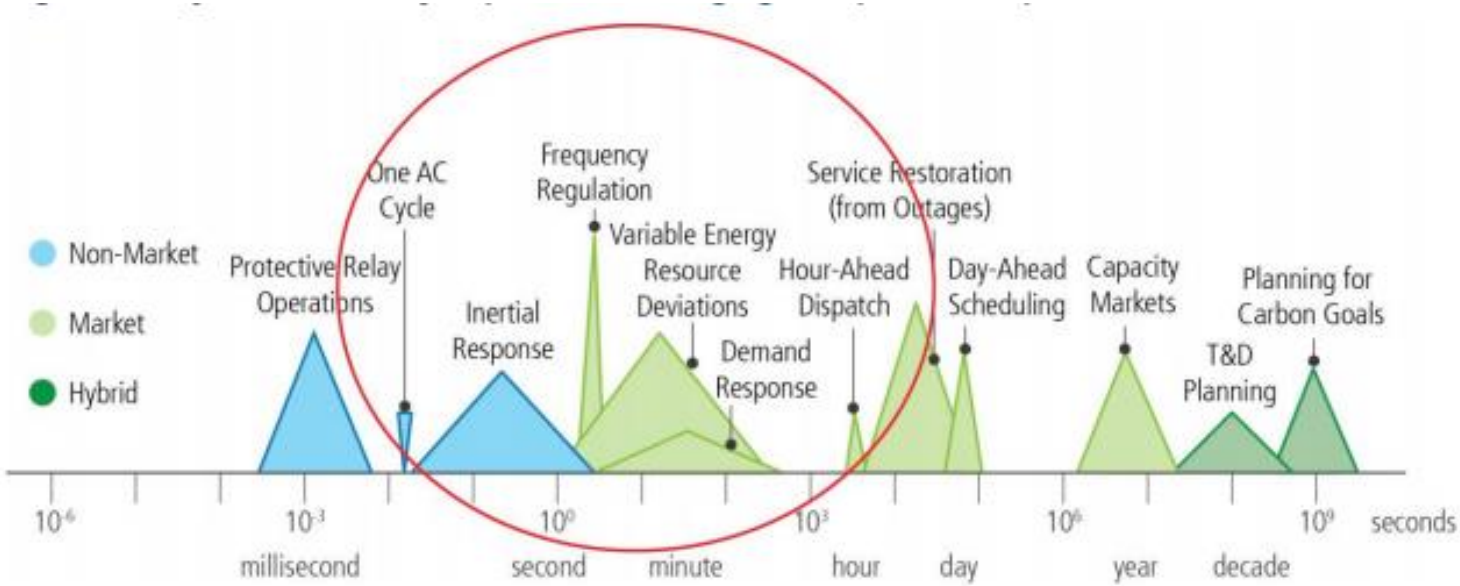


Image Source: DTE Energy

Energy Resilience

Mitigation measures used for grid resilience depend on the vulnerabilities and threats, but may include:

- Undergrounding critical lines
- Demand-Side Energy Efficiency
- Diversifying Generation
- Deploying Distributed Generation: Distributed PV, Microgrids, Energy Storage Solutions
- Smart Grids



Graphic source: DOE

Solar PV + Resilience

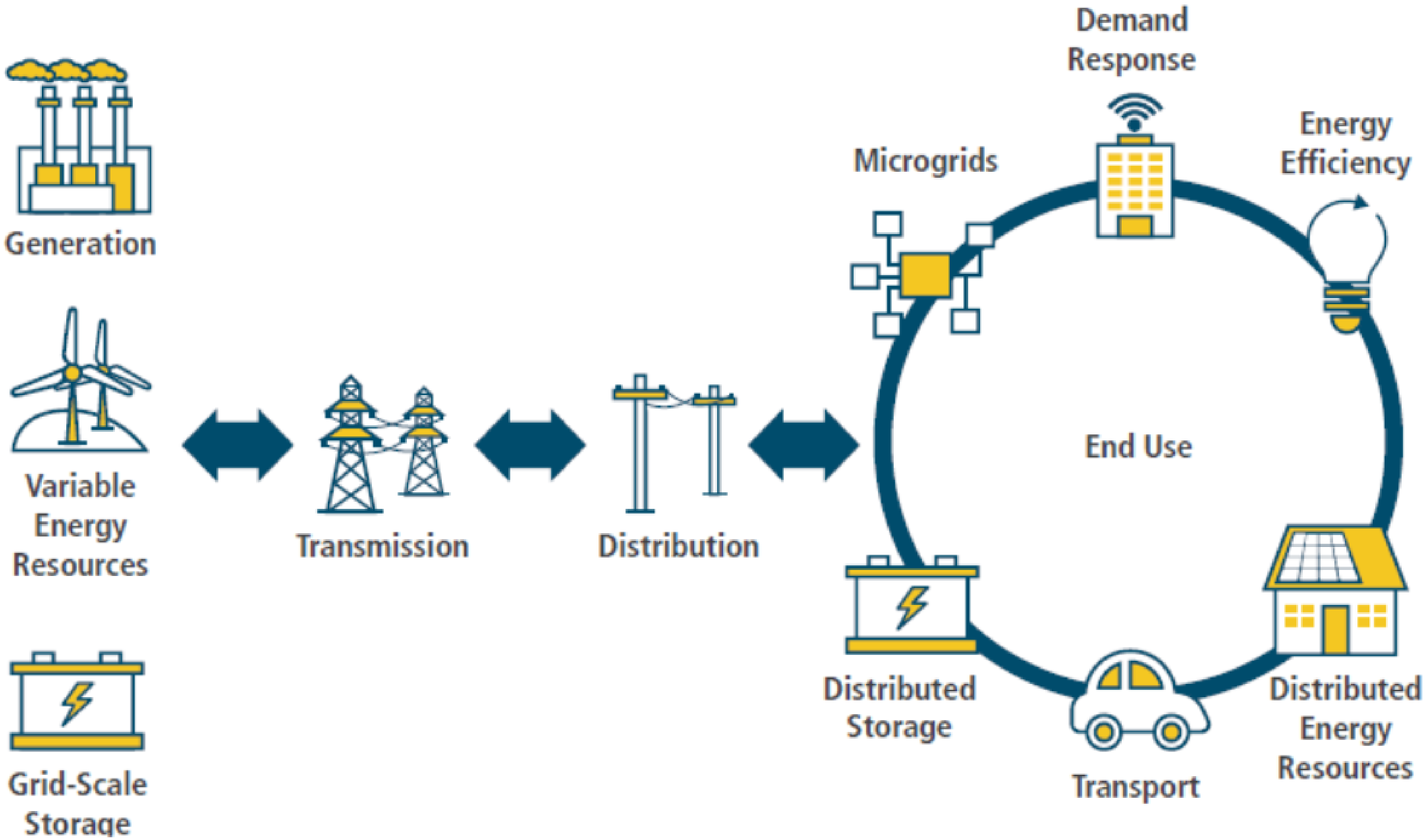
Image Source: Kenny Chung, http://kennychung.net/photo/scenic-urban/hurricane-sandy-blackout-nyc/05-manhattan-skyline-blackout.jpg

Solar PV + Resilience

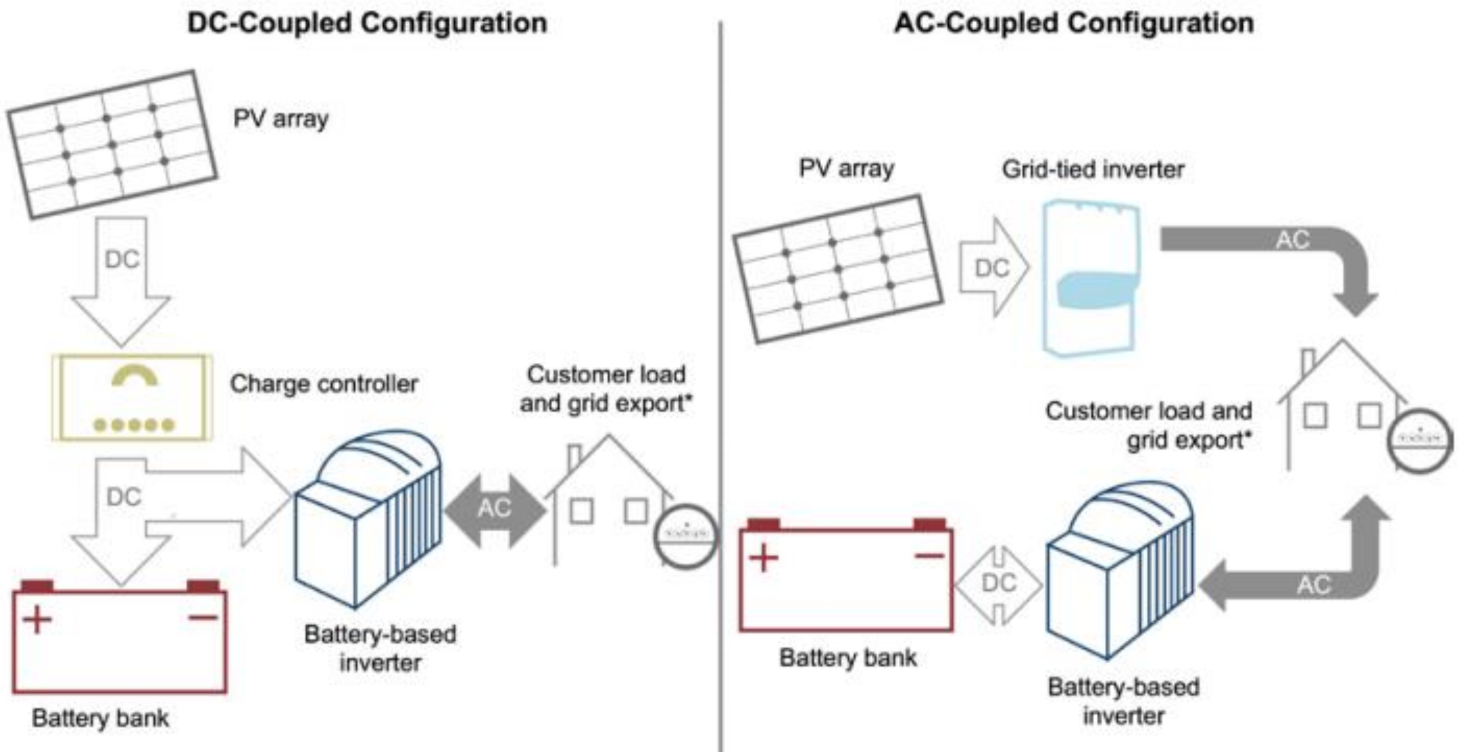
Onsite renewable energy technologies alone do not equate to a resilient system.

Image Sources:
Eliza Hotchkiss, NREL, Camden County MUA: http://www.ccmua.org/

Solar PV + Resilience



Solar PV + Resilience

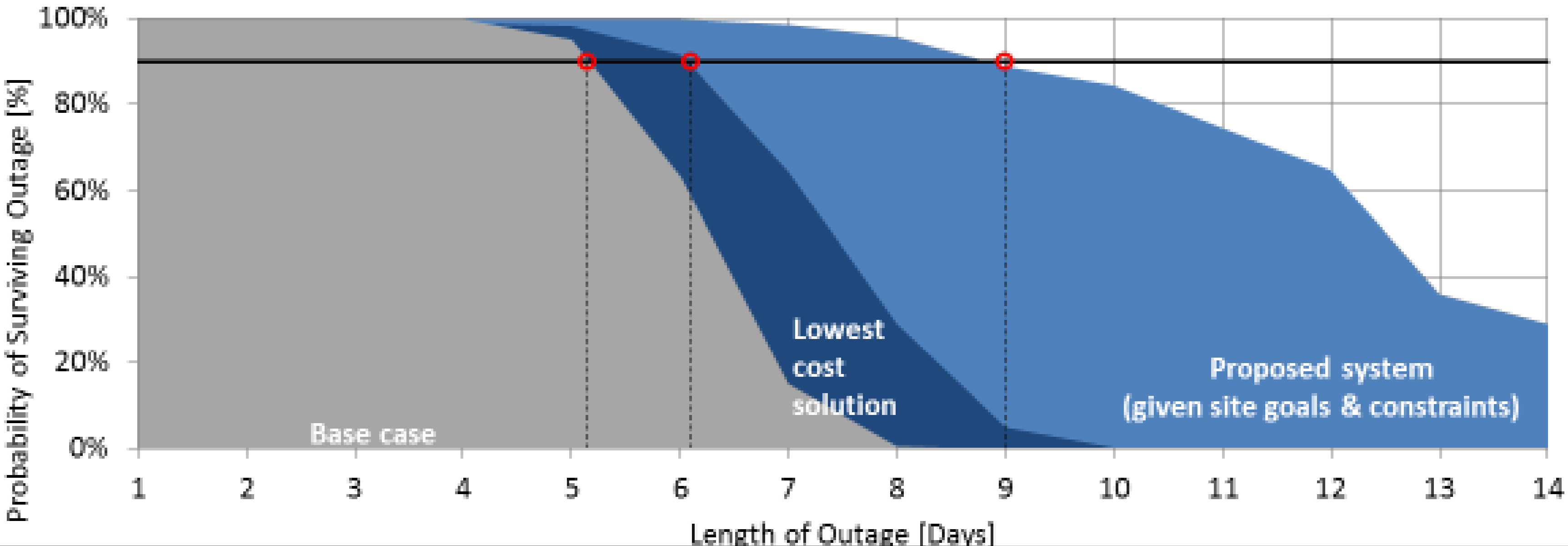


Source: Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016. Kristen Ardani, Eric O'Shaughnessy, Ran Fu, NREL; Chris McClurg, RMI; Joshua Honeycutt, U.S. DOE

Example: PV + Battery combined with existing diesel genset extends probability of surviving outage at a lower or marginally higher cost

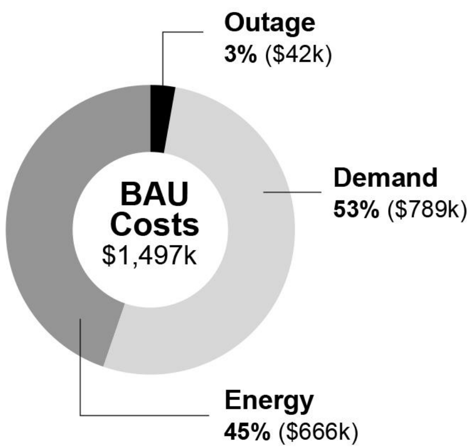
NREL evaluated thousands of random grid outages and durations throughout the year and compared number of hours the site could survive with a diesel gensets and fixed fuel supply vs. gensets augmented with PV and battery

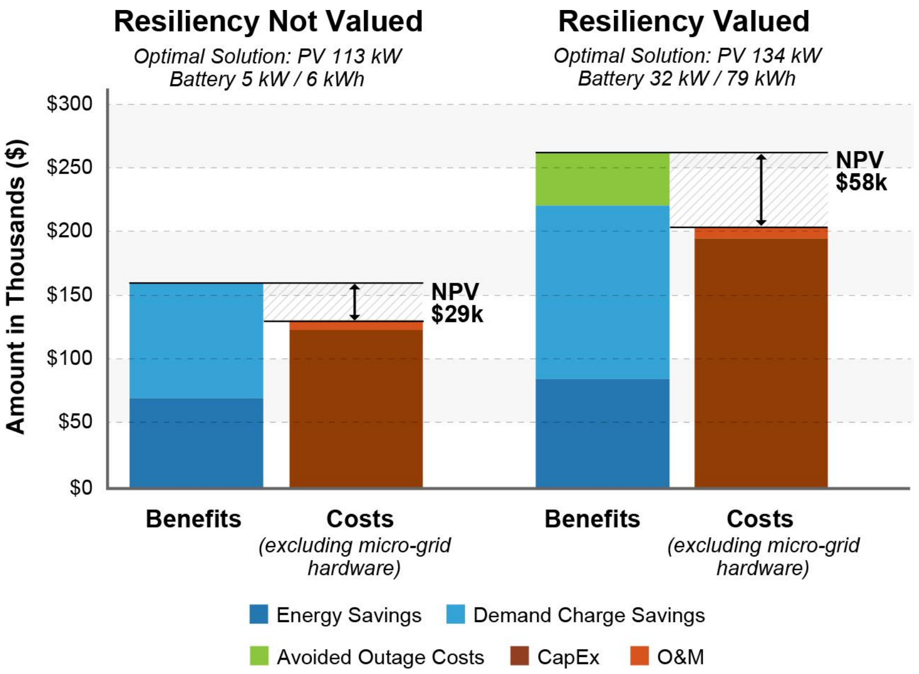
	Generator	Solar PV	Storage	Lifecycle Cost	Outage
1. Base case	2.5 MW	-	-	$20 million	5 days
2. Lowest cost solution	2.5 MW	625 kW	175 kWh	$19.5 million	6 days
3. Proposed system	2.5 MW	2 MW	500 kWh	$20 .1million	9 days



Solar PV + Resilience

- Prioritizing projects based on loads, criticality, best technical options, financial considerations, etc.





Source: Laws, Nicholas D., Kate Anderson, Nicholas A. DiOrio, Xiangkun Li, and Joyce McLaren. "Impacts of Valuing Resilience on Cost-Optimal PV and Storage Systems for Commercial Buildings." Manuscript submitted for publication.

Solar PV + Resilience

- Siting systems so they can withstand natural hazards and be physically resilient is important

Source: Eliza Hotchkiss, NREL

Solar PV + Resilience

- Siting systems so they can withstand natural hazards and be physically resilient is important
  - Torque bolts to specifications
  - Do not site where wind will create uplift (e.g., prevent rooftop overhangs)
  - Use through-bolt techniques
  - If clamps are utilized ensure adequate materials are being used, are to code/standards and are installed appropriately
  - Protect from extreme locations through siting and design considerations or incorporate pre-storm maintenance routines

Solar PV + Resilience

System design considerations and specifications in summary:

- On-site generation, sizing/capacity for optimum performance
- Islanding controls and energy storage
- Site design to ensure minimal damage
- Procurement and financing options, additional costs and benefits

Defining Resilience

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Energy Resilience

Solar PV + Resilience

Best Practices

Solar and PV Resilience Success Stories

- Florida SunSmart Schools and Emergency Shelters
  - Launched in 2009 and ongoing
  - 115 schools with 10 kW PV systems coupled with storage
  - Schools have operated through recent disasters
- Borrego Springs Microgrid
  - Launched in 2012
  - Microgrid Configuration
    - 26 MW PV
    - Two 1.8 MW Batteries
    - Automated DR
  - Microgrid withstood 20-hour grid outage
- Stafford Hill, Vermont Microgrid
  - Constructed in 2015
  - Microgrid Configuration
    - 2.4 MW PV
    - 4 MW Storage
  - Results in $200,000 peak demand savings/year
  - Provides emergency shelter services in times of grid outages

Success Stories Continued

- Marcus Garvey Apartments Microgrid (Brooklyn, New York)
  - Constructed in 2015
  - Microgrid Configuration
    - 400 kW PV
    - 300 kW storage
    - 40 kW fuel cell
  - Provides 4 hour daily load reduction and resiliency during outages
  - Project incorporates blockchain-supported transactive energy market for residents
- Massachusetts (February 2018)
  - $1.5 million granted to 14 communities for resilient microgrid feasibility studies
    - Palmer, Massachusetts
      - Analysis of microgrid covering emergency management, hospital, wastewater treatment, and other facilities

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Best Practices and Resources

- How Solar PV Can Support Disaster Resilience https://www.nrel.gov/technical-assistance/blog/posts/how-solar-pv-can-support-disaster-resiliency.html
- Resilience Video from the City of Denver as part of NREL's Video Submission Contest Summer 2017: www.youtube.com/watch?v=T_AbO7aLoFw&feature=youtu.be
- NY solar map: https://nysolarmap.com/
- San Francisco's resilient PV tool uses PV Watts: http://solarresilient.org/
- Microgrid Ready Fact Sheet https://www.nrel.gov/docs/fy18osti/70122.pdf
- Distributed Solar PV for Electricity System Resilience: https://www.nrel.gov/docs/fy15osti/62631.pdf
- Valuing the Resilience Provided by Solar and Battery Energy Storage Systems https://www.nrel.gov/docs/fy18osti/70679.pdf

Case Study: Lyons, CO

https://www.youtube.com/watch?v=L1xaNsZxOJ4

Homework

Additional activities to support resilient PV system implementation

Homework

1. Does your state or jurisdiction have any resilience policies or goals?

2. Do the policies or goals relate specifically to resilient energy? If so, what are the details (e.g., are microgrids encouraged, are islanding controls required, is energy storage allowed?)

3. How can your current policies or incentives be enhanced to incorporate resilient clean energy systems?

4. How would your jurisdiction or state prioritize limited funds to implement resilient clean energy systems?

5. Do you feel like you understand enough about resilient PV systems to be able to inform and influence stakeholders in your state or jurisdiction to implement more of these systems?

Knowledge Checks

1. How is **resilience** being defined in this training?

- ❑ A. The ability of a substance or object to spring back into shape, like nylon
- ❑ B. The ability of a group of individuals to cope with stress, trauma, post-traumatic stress disorder
- ❑ C. The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through adaptable and holistic planning and technical solutions.
- ❑ D. None of the above

Answer: C

Knowledge Checks

2. Why is energy resilience important to states and local governments?

- ❑ A. To reduce the impact of large-scale disasters
- ❑ B. To protect property, assets and prevent loss of life
- ❑ C. To provide clean, reliable power
- ❑ D. All of the above

Answer: D. All of the above.

Knowledge Checks

3. A resilient PV system will include…

- [ ] A. Islanding controls
- [ ] B. Energy storage
- [ ] C. Pumped hydro and fuel cells
- [ ] D. Well designed and hardened PV panels to prevent damage in storms.

Answer: A, B, and D.

Knowledge Checks

4. True or False: Solar PV is not currently being used to enhance resilience

- ❑ True
- ❑ False

Answer: FALSE. Many communities, cities and states are installing solar PV to enhance resilience.

Thank You

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Questions? Contact Eliza.Hotchkiss@nrel.gov

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