Introduction to Resilience for Electricity Systems

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Resilience Training for States – Western Region

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Agenda

- Introducing Resilience:
    - Defining Resilience
    - Understanding Risks
    - Causes and Consequences
    - Qualitative and Quantitative Approaches
- Mitigation and Resilience Solutions
    - Example of Stakeholder Driven Approach
- Resources for more information
- Q&A

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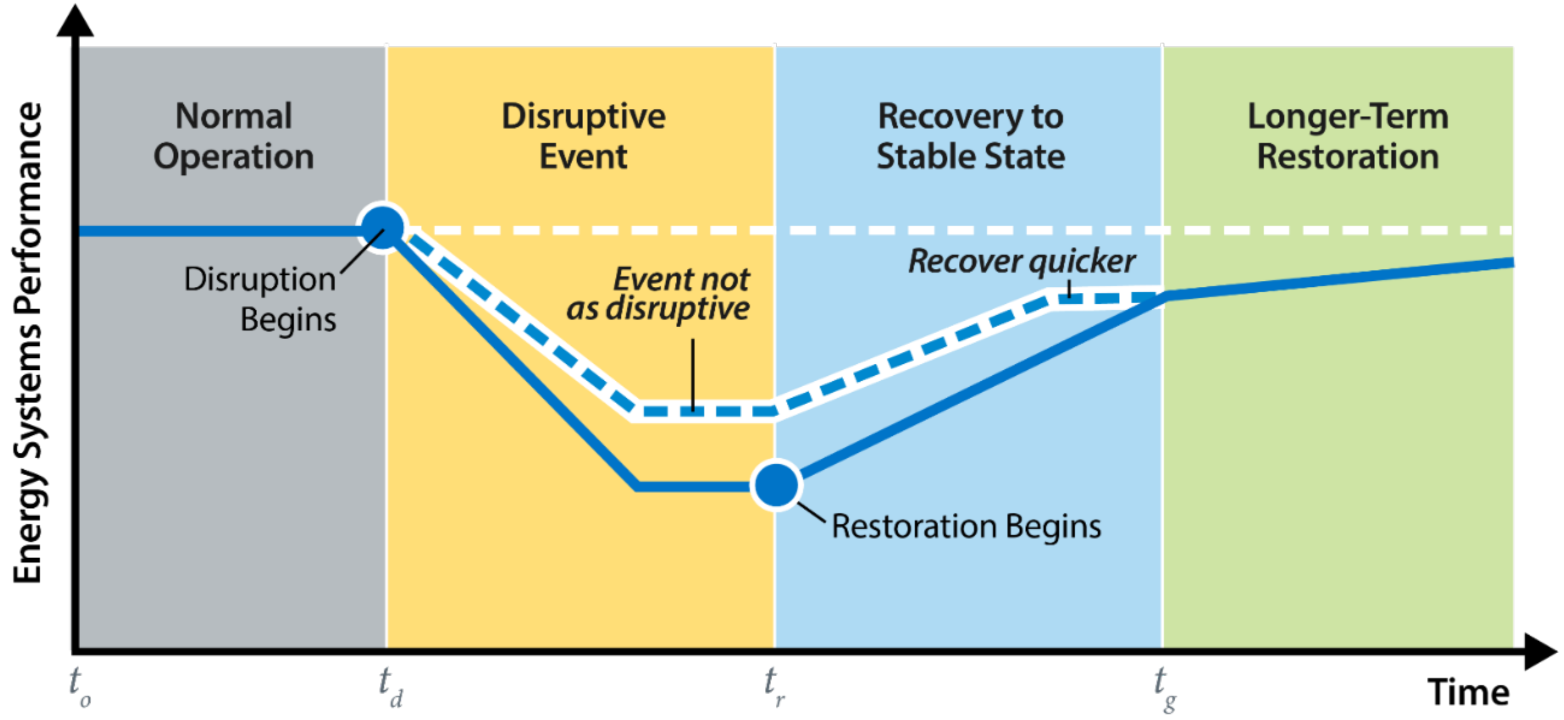
Introducing Resilience

Established Resilience Definitions

The ability to anticipate, prepare for, and adapt to changing conditions and to withstand, respond to, and rapidly recover from disruptions through adaptable and holistic planning and technical solutions.[1]



Resilience can be measured as a system's performance subject to both acute shocks and chronic stresses.

Resilience is contextual. A system resilient to one type of hazard may not be resilient to another.

Types of shocks and stresses:

- Natural
- Human caused
- Systemic.

Types of systems:

- Engineered system (e.g., power grid)
- Social system (e.g., communities)
- Geographically defined systems (e.g., military installation).

[1]Hotchkiss, Eliza; Dane, Alex. 2019. Resilience Roadmap: A Collaborative Approach to Multi-Jurisdictional Resilience Planning. Golden, CO. National Renewable Energy Laboratory. NREL/TP-6A20-73509. https://www.nrel.gov/docs/fy19osti/73509.pdf.

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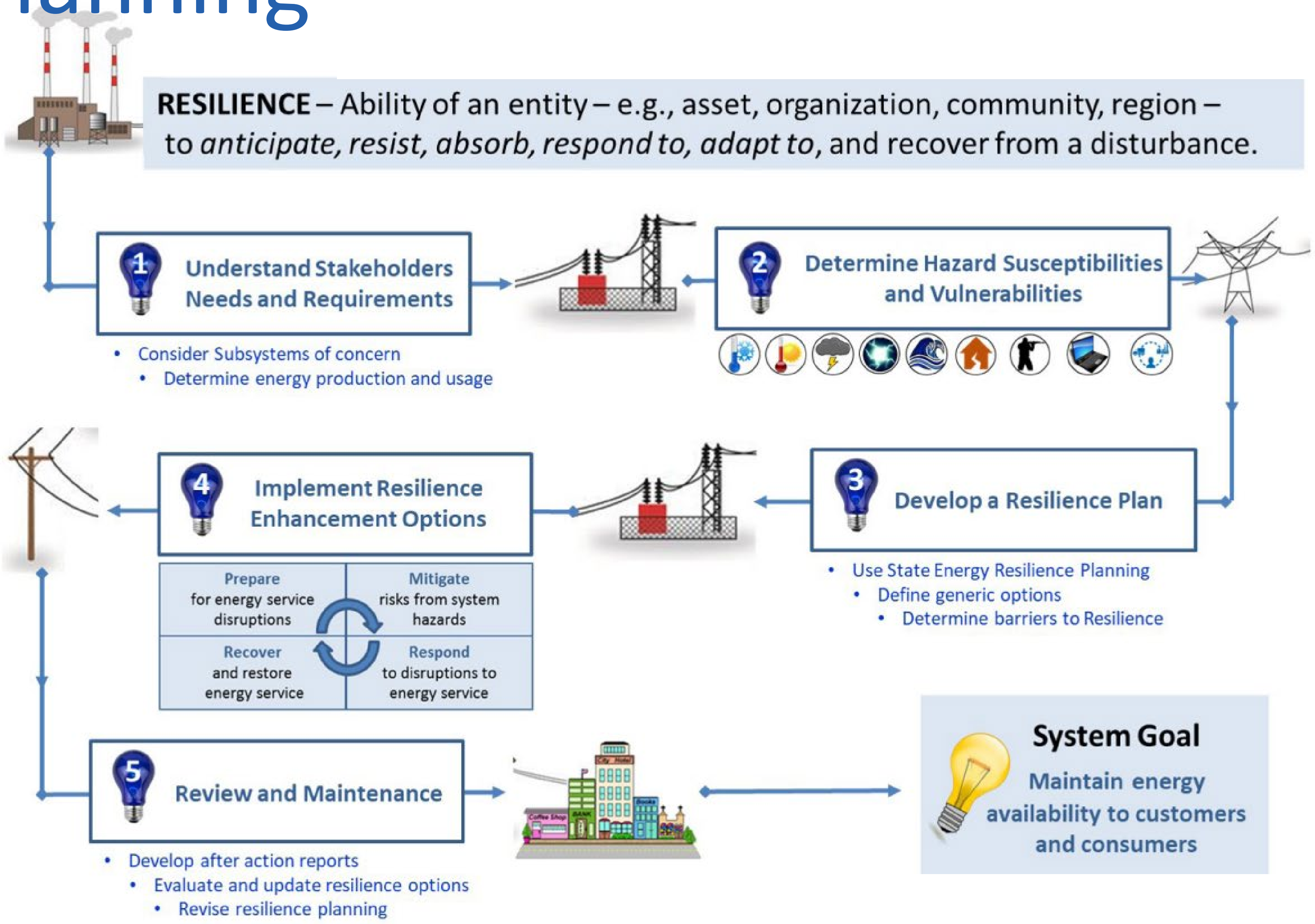
A Risk Informed Approach to Resilience Assessments and Planning

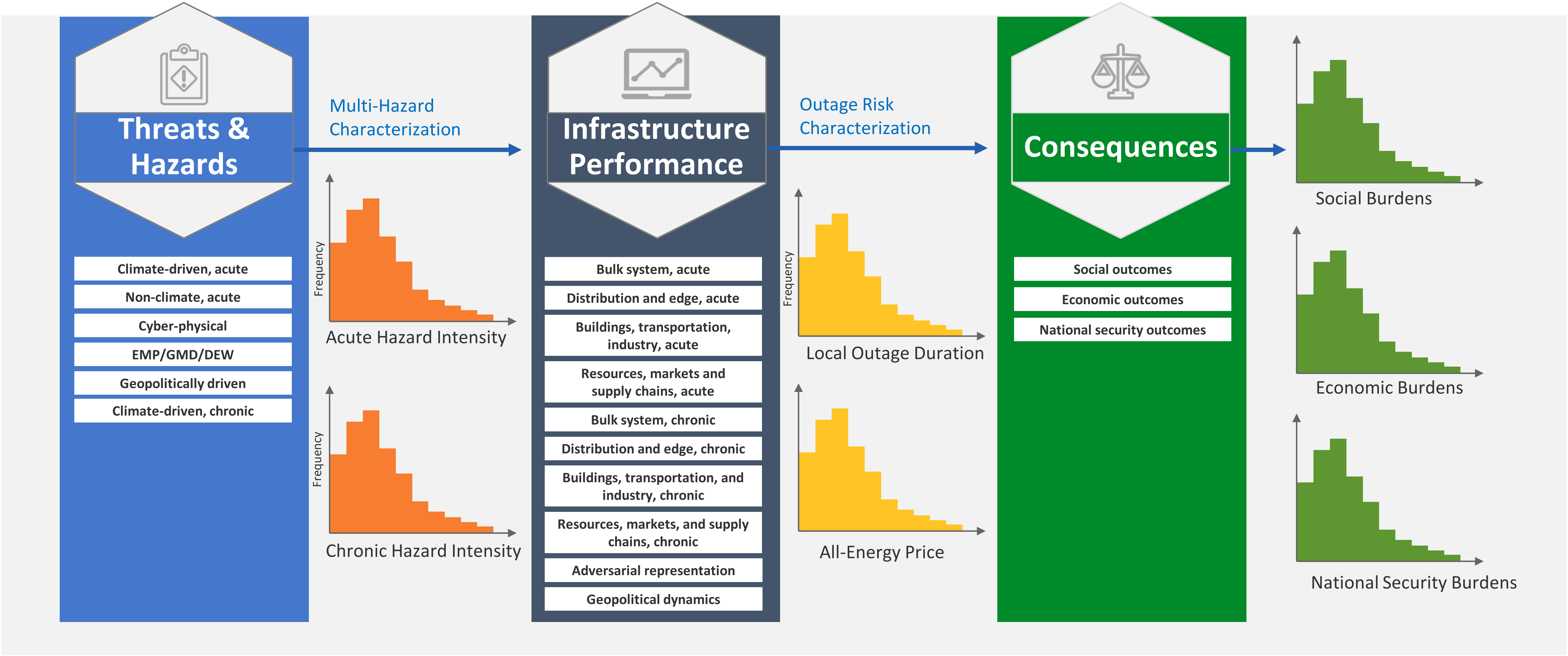
Illustration by Jennifer Breen Martinez, NREL



K. Anderson, E. Hotchkiss, L. Myers, and S. Stout, "Energy Resilience Assessment Methodology," *Renewable Energy*, p. 29, 2019.

State Energy Resilience Framework, J. Phillips, M. Finster, J. Pillon, F. Petit, and J. Trail, Global Security Sciences Division, Argonne National Laboratory, December 2016, https://publications.anl.gov/anlpubs/2017/02/133591.pdf.

Resilience Components



Definitions

Hazard: Anything that can expose a vulnerability, either intentionally or accidentally, or that can damage, destroy or disrupt the power sector. Hazards can be natural, technological, or human caused. They are typically not within the operator's control and can include wildfires, hurricanes, storm surge, cyber-attacks and so on. Often used interchangeably with *threat*.

Threat: Something that is likely to cause damage or danger to the power sector. Often used interchangeably with *hazard*.

Vulnerability: A weakness in a system or process which, when exposed, can lead to a negative impact or consequence. Typically, vulnerabilities are within control and can be mitigated to avoid exposure.

Impact or Consequence: To have a direct effect or significant effect on something such as the power sector or components of the system.

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Hazards and Threats

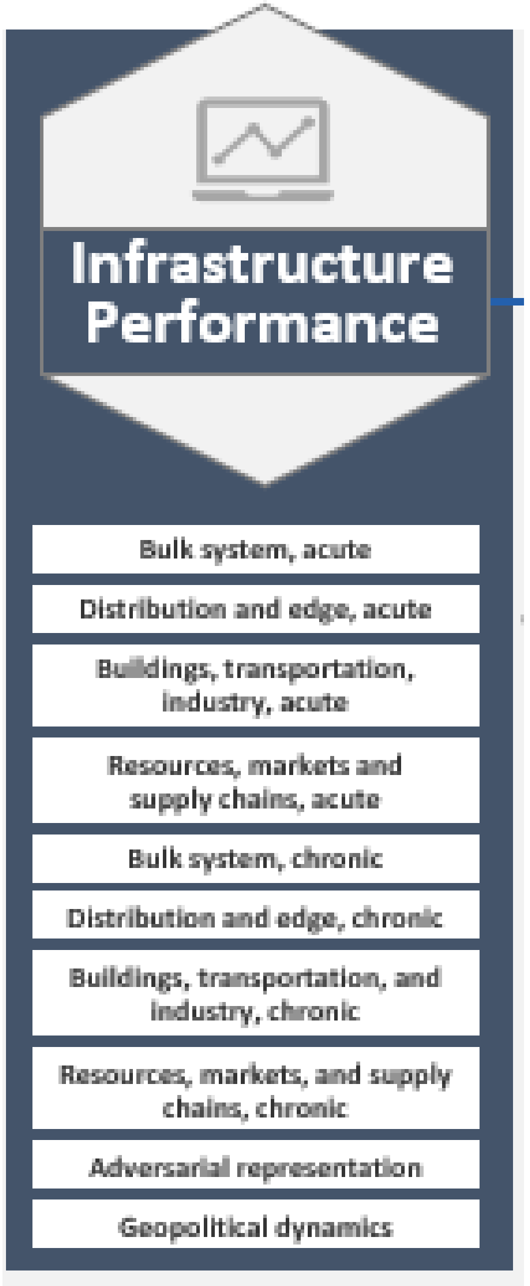
Types of shocks and stresses:

- Natural
- Human caused
- Systemic

Types of systems:

- Engineered system (e.g., power grid)
- Social system (e.g., communities)
- Geographically defined systems (e.g., military installation)

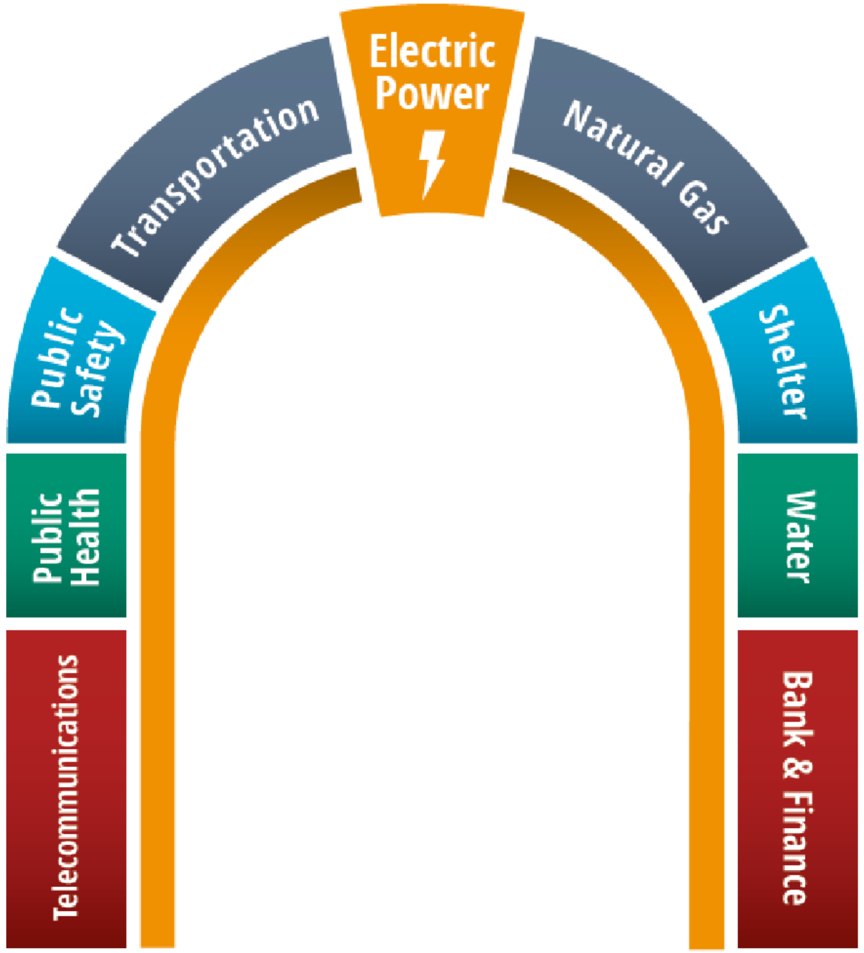
Vulnerabilities



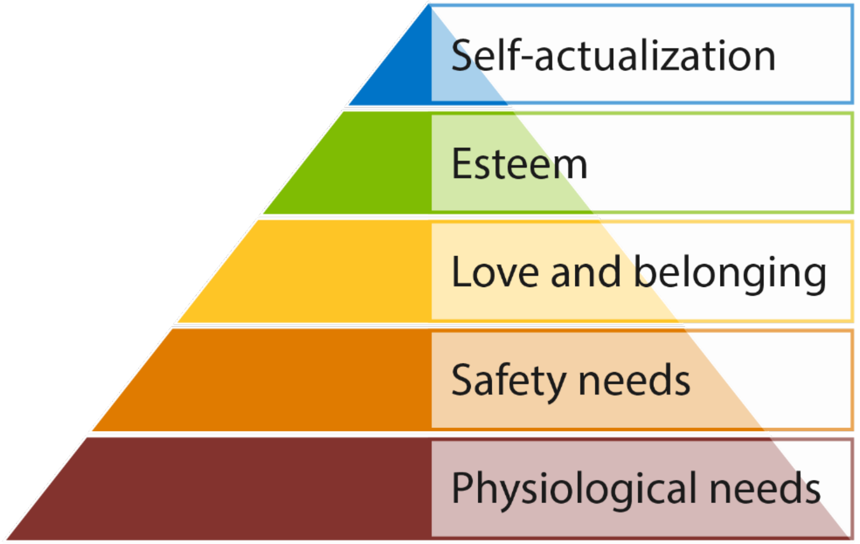
- Power sector vulnerabilities usually fit into two categories:
  - Infrastructure
  - Process
- Both types of vulnerabilities need to be considered when assessing resilience options for the power sector
- Infrastructure vulnerabilities are often easy to address but tend to be very expensive
  - Power system hardening
  - Large infrastructure development
- Process vulnerabilities tend to be difficult to address but usually require relatively inexpensive fixes
  - Trainings
  - Development of codes and standards

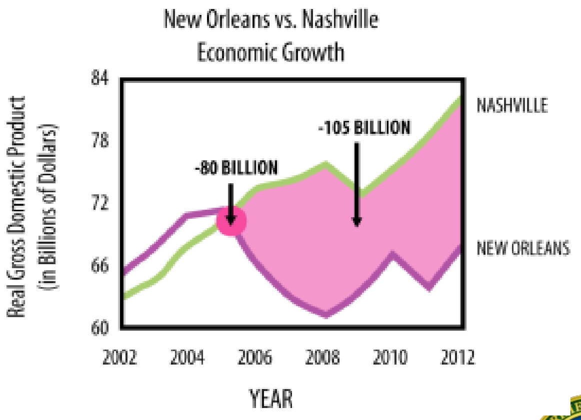
Consequences

Within resilience, there are three major dimensions of consequence. These better define the externality and **lead to different internalization pathways**.

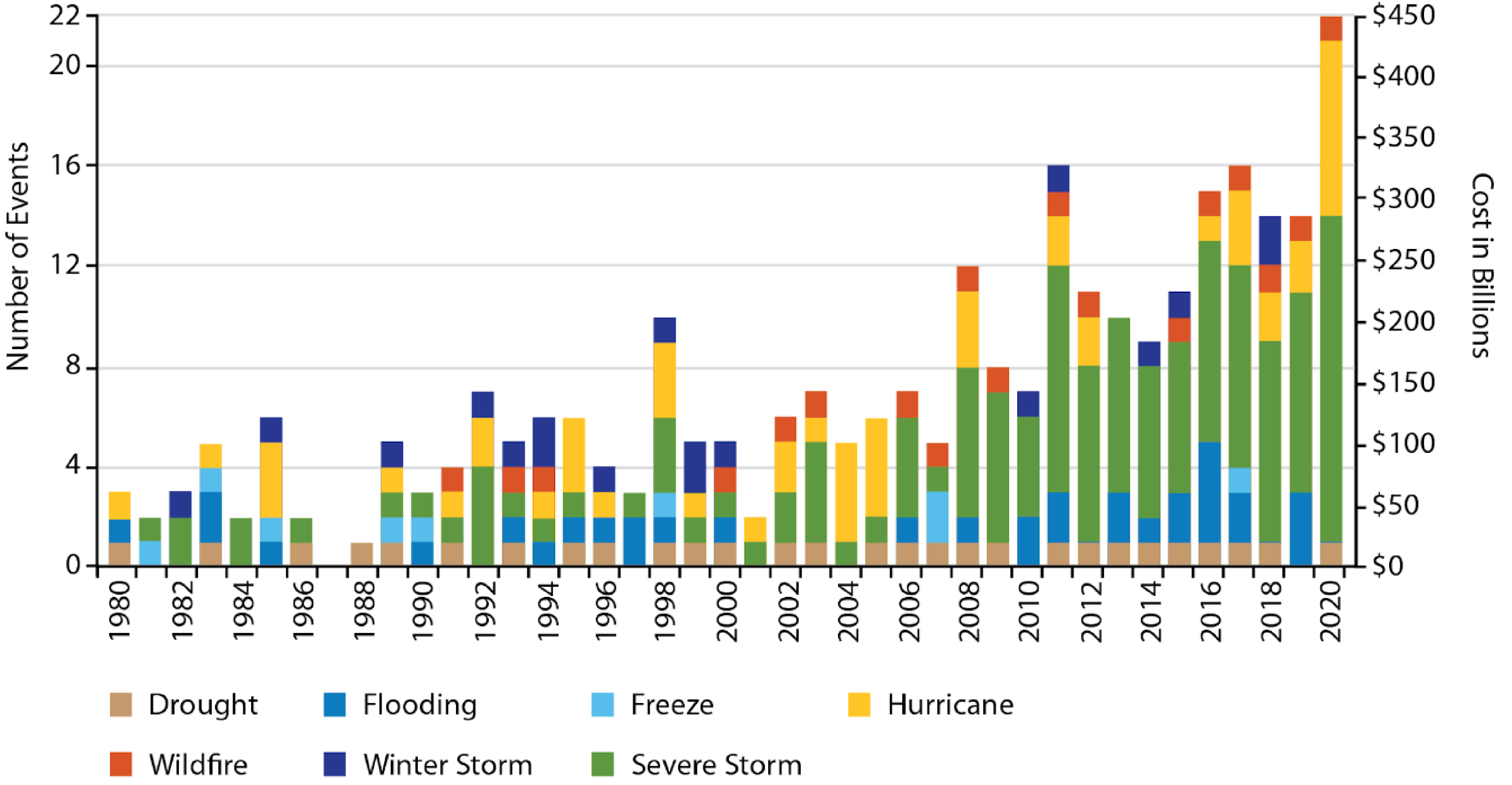


- **Society**
- **Economy**
- **National Security**

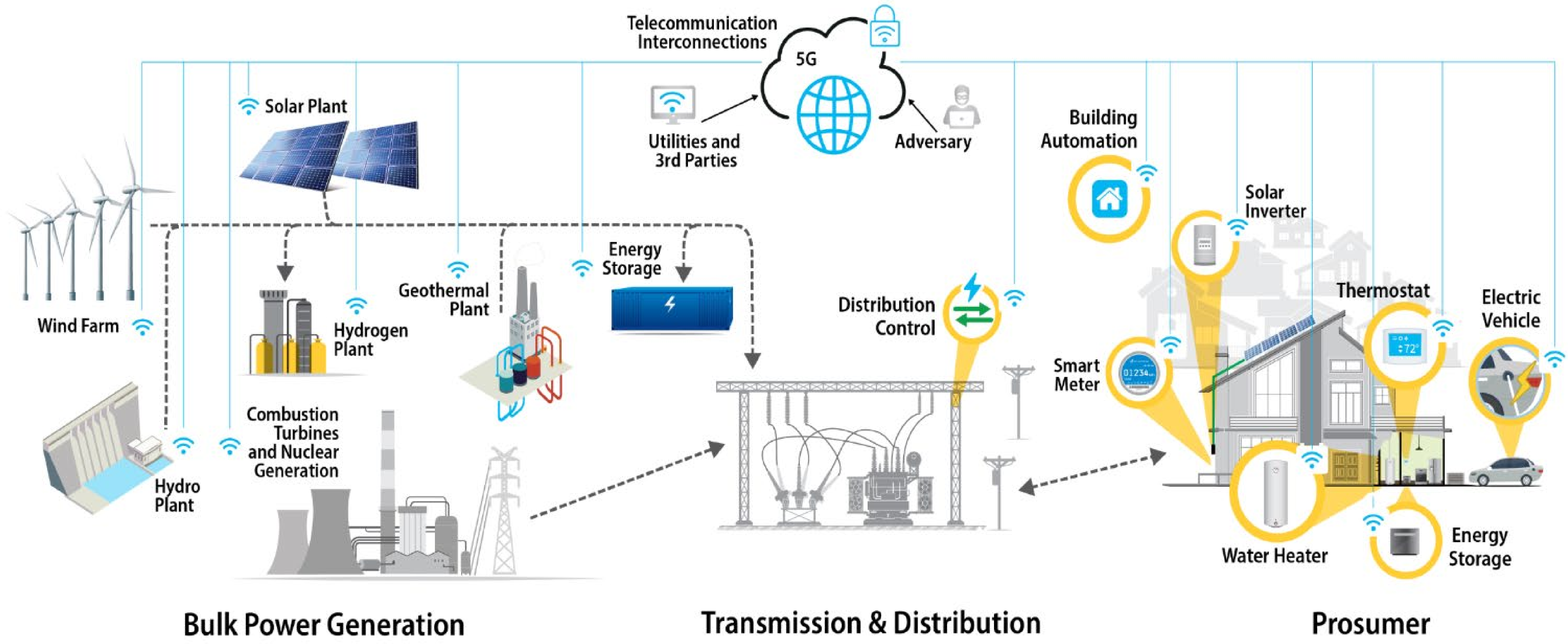




United States Billion-Dollar Disaster Events



Source: NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2021). https://www.ncdc.noaa.gov/billions/, DOI: 10.25921/stkw-7w73



A New Frontier:

The grid is evolving to become more distributed, intelligent, and complex.

Coupled with aging infrastructure, the vulnerabilities of emerging energy systems to disruption are not yet well understood.

Resilience Solutions

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Risk Informed Approach to Assessments and Planning

- Data Gathering and Goal Setting
- Vulnerability and Risk Assessment
- Resilience Options
- Prioritization and Implementation
- Assessment and Review

Energy

- **Energy Efficiency**
  Energy efficient buildings not only lower energy bills but can also allow occupants to shelter in place during a disruptive event. Architectural design concepts, such as passive survivability, can be incorporated to help vulnerable populations avoid life-threatening situations.

- **Grid Hardening**
  Weatherizing equipment, installing fire-resistant technologies, undergrounding lines, and strengthening utility poles can reduce the likelihood of power outages.

- **Distributed Energy Resources**
  Microgrids are islandable onsite energy generation (e.g., rooftop solar, wind, fuel cells) paired with energy storage solutions that can provide power to buildings or systems during disruptive events when the grid system may not be operational.

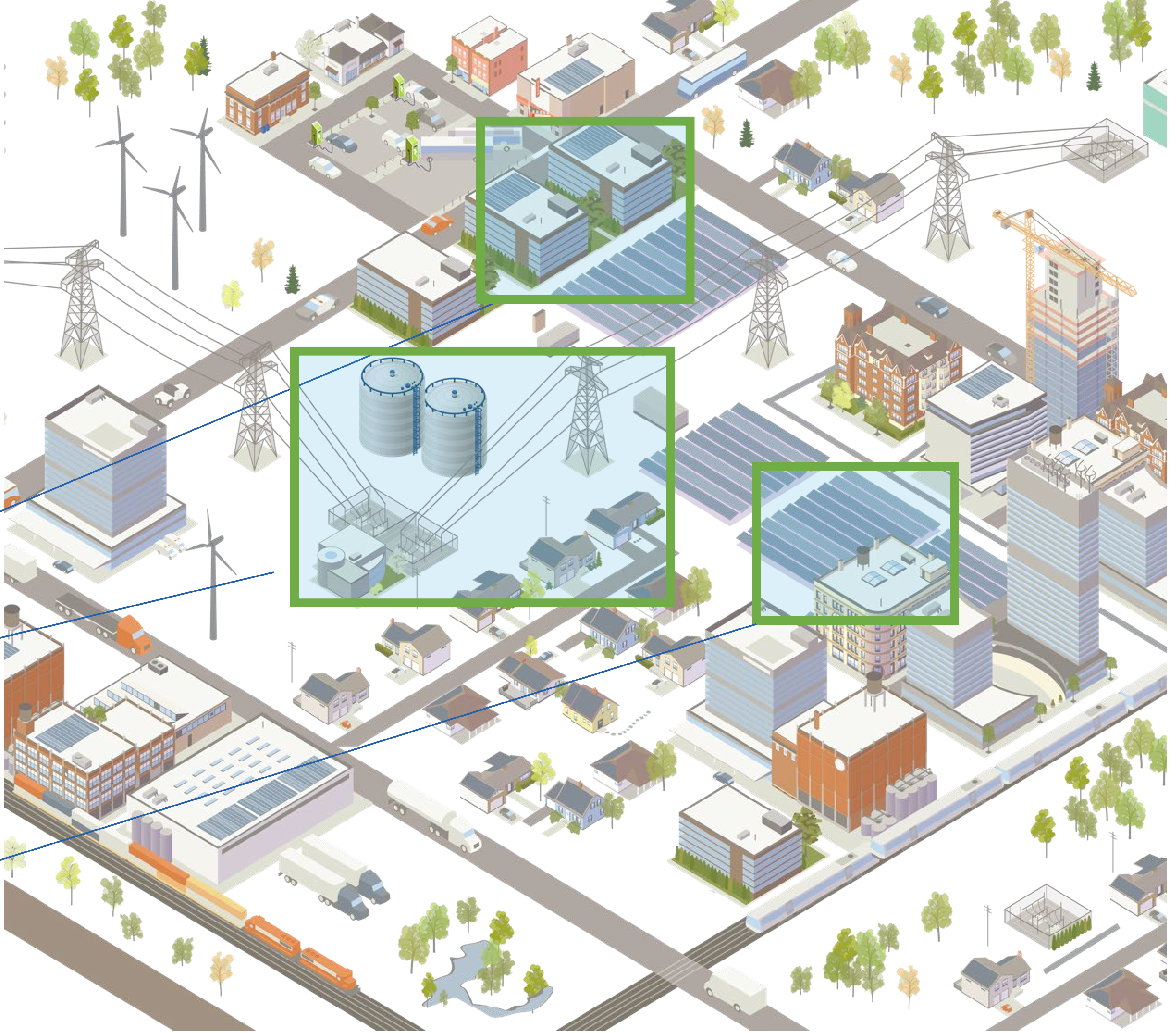

Image credit: Anthony Castellano, NREL

Transportation

- **Fuel diversity**
  Multiple modes of transportation and fuels can enhance resilience for daily needs *and* during disruptive events. Electric vehicles, walkable cities, and diversifying fuels can help meet transportation needs during disruptions.

- **Resilient infrastructure**
  Hardened infrastructure, porous pavements, and reinforced bridges can ensure that transportation routes are sustained during and after disruptive events.

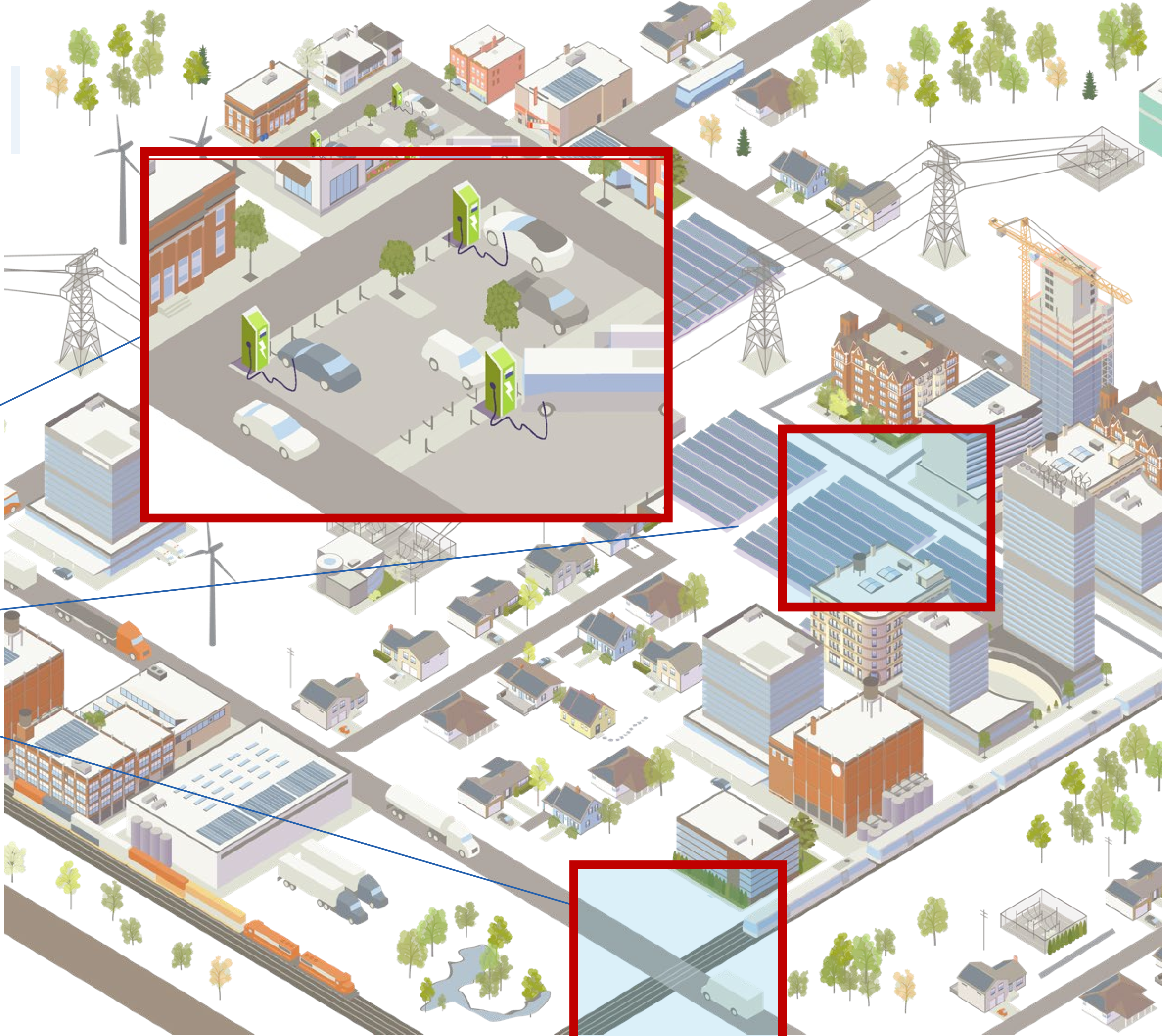

Image credit: Anthony Castellano, NREL

Water

- **Conservation and Storage**
  Reducing the amount of water used within a building or process and having onsite water storage or a rainwater harvesting system can help meet water needs during a disruption to a municipal water supply.

- **Gravity Fed Systems**
  Using gravity to distribute water is a resilient solution because energy is not needed during normal operating conditions and disruptive events.

- **Green Infrastructure**
  Solutions such as using natural vegetation and bioswales can reduce localized flooding associated with storms and slow runoff rates.

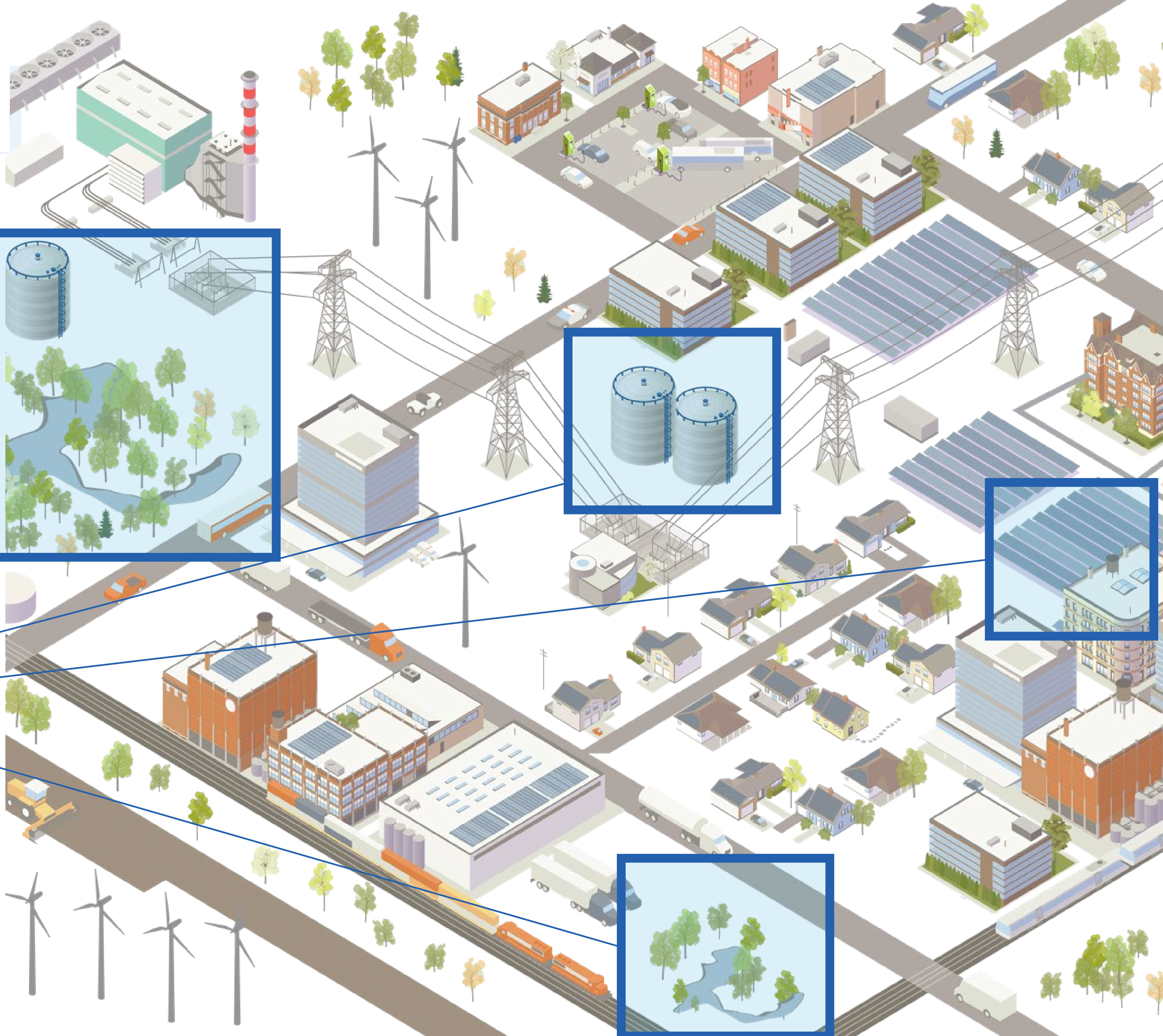

Image credit: Anthony Castellano, NREL

Information and Communication

- **Cybersecurity**
  Ensuring a secure cyber architecture is built into communications and IT networks will reduce risks associated with attacks and hacking, ensuring systems are operational.

- **Redundancy and Resourcefulness**
  Analogue backup systems and controls, redundant nodes, and trained workforce can increase the resilience of communications networks to all sorts of threats and hazards.

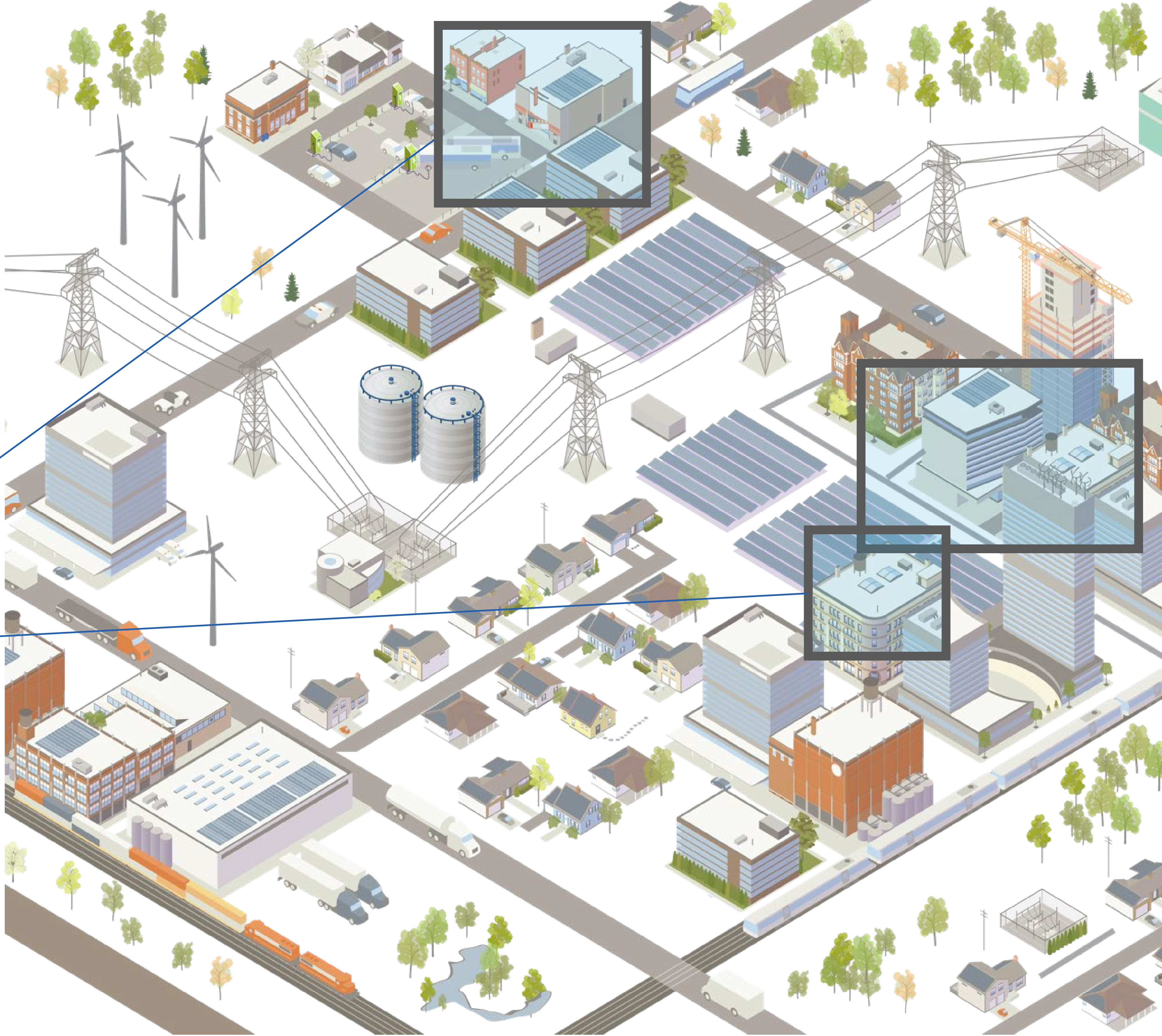

Image credit: Anthony Castellano, NREL

Questions to Ask Utilities

- What hazards, threats, or vulnerabilities are you most concerned with for your utility, community, or state?
- What tools do you use to assess hazards, threats, and vulnerabilities?
  - Are you considering climate change and changing impacts?
  - How far in the future are you modeling?
- Have you prepared resilience plans?
  - Are those public or at least shared with state agencies?
  - How do you involve stakeholders in developing these?
- What resilience metrics are being used?
  - How do you measure progress for resilience investments?
  - How do you measure the costs and benefits of resilience investments and is that data shared with the PUCs? Other state agencies?
- Are you assessing risk holistically across the entire system? Are mitigation measures assessed across the entire system?

Resources for more information

Resources

Research and Resources

- Energy Resilience Assessment Methodology: https://www.nrel.gov/docs/fy20osti/74983.pdf
- Valuing Resilience in Electricity Systems: https://www.nrel.gov/docs/fy19osti/74673.pdf
- Technical Resilience Navigator (NREL and PNNL): https://trn.pnnl.gov/
- Customer Damage Function Calculator: https://cdfc.nrel.gov/
- Energy Security and Resilience Research: https://www.nrel.gov/security-resilience/
- State Energy Resilience Framework, J. Phillips, M. Finster, J. Pillon, F. Petit, and J. Trail, Global Security Sciences Division, Argonne National Laboratory, December 2016, https://publications.anl.gov/anlpubs/2017/02/133591.pdf.

DOE Grid Deployment Office Resources

- Grid Resilience State & Tribal Formula Grant Program: Grid Resilience State/Tribal Formula Grant Program | Department of Energy
- Grid Resilience and Innovation Partnerships (GRIP) Program: https://www.energy.gov/gdo/grid-resilience-and-innovation-partnerships-grip-program
- Grid Deployment Office: https://www.energy.gov/gdo/grid-deployment-office

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Contact

https://www.energy.gov/gdo/grid-deployment-office

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