Overview of Resilience Planning Framework

PRESENTED BY

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Sandia National Laboratories

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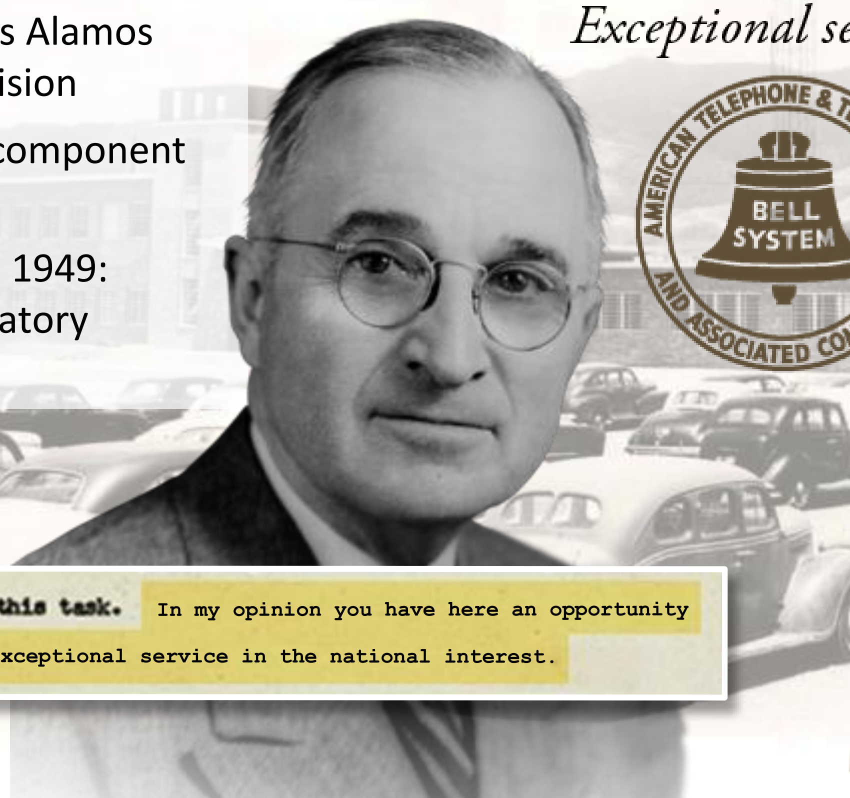
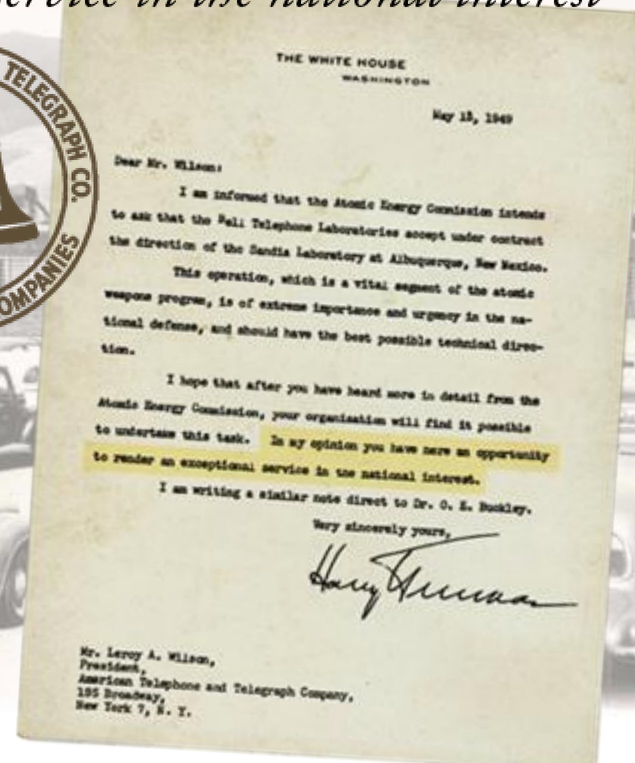
SAND2018-10895 PE.

Sandia's History

- July 1945: Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949: Sandia Laboratory established

Exceptional service in the national interest





THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

Timeline: Sandia Energy Programs

1970 | 1980 | 1990 | 2000 | 2010 | 2011 | 2012 | 2013

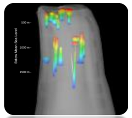
Energy crisis of the 1970s spawned the beginning of significant energy work

Vertical-axis Wind Turbine

NRC cask certification studies & core melt studies

Solar Tower opens

Strategic Petroleum Reserve



Combustion Research Facility (CRF) opens to researchers

Distributed Energy Technology Laboratory (DETL)

DOE's Tech Transfer Initiative established by Congress in 1991

MELCOR code released

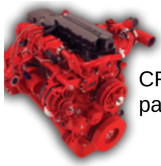
Power grid reliability study

SunCatcher™ & Stirling Energy Systems

METAL HYDRIDE CENTER OF EXCELLENCE

Energy Policy Act of 2005

Advent Solar

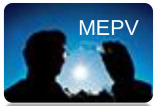


CRF & Cummins partnership

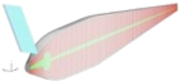
Joint BioEnergy Institute

Sunshine to Petrol Pilot Test

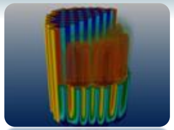
Large-scale pool fire tests of liquefied natural gas (LNG) on water



Mesa del Sol microgrid demo

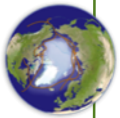


Water Power Program



Consortium for Advanced Simulation of Light Water Reactors (CASL)

Climate study uncertainties to economies



Combustion Research Computation and Visualization (CRCV) opens

Criegee combustion intermediates

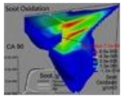
PV Regional Test Centers (RTCs)

Sandia Cooler

CREW published

Fukushima Recovery

Solar Glare Analysis Tool (SGHAT)



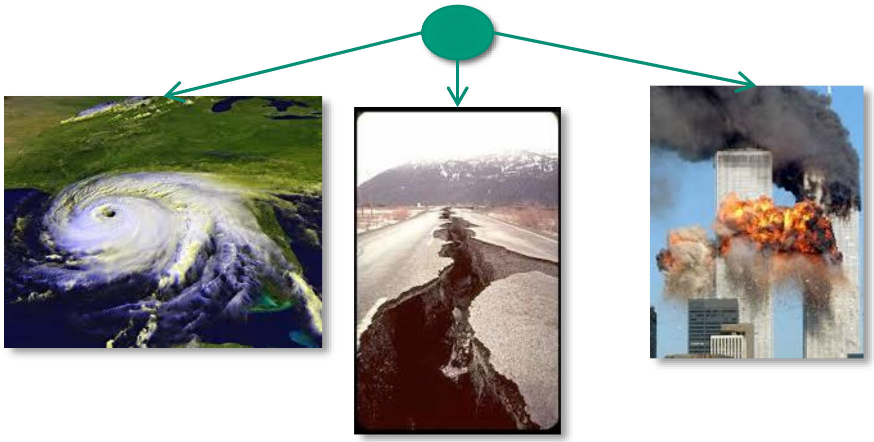
New diesel low-temp combustion model

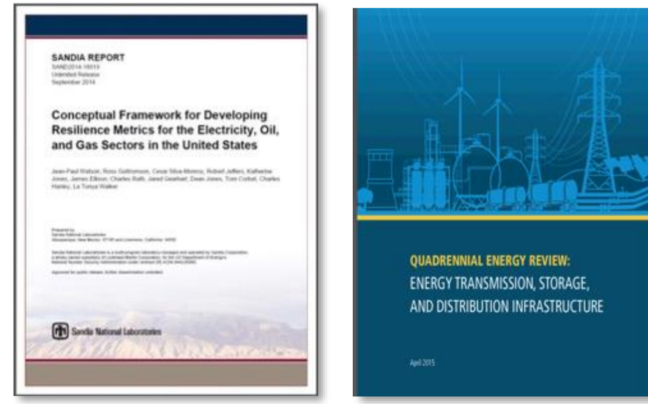
Biofuels: ionic liquid pretreatment

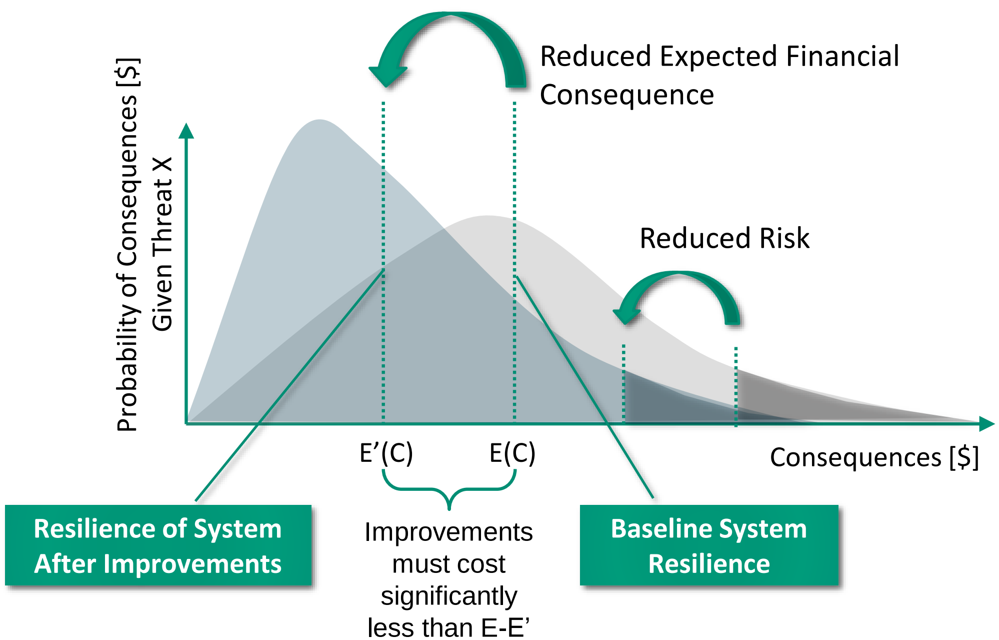
Electricity Storage Handbook

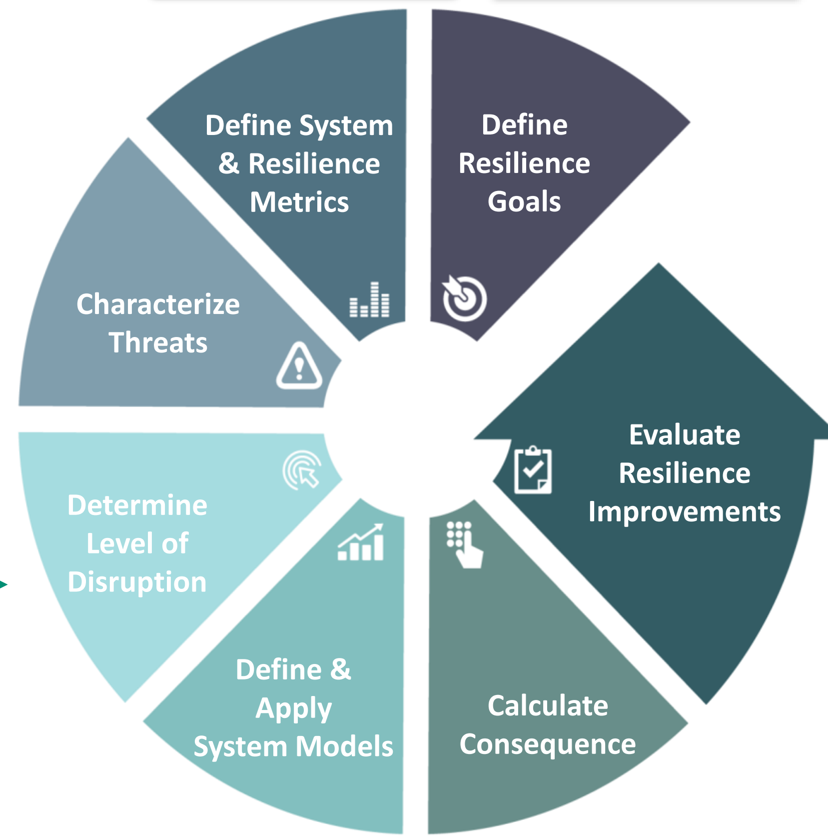
AMII increases US wind blade manufacturing

Resilience Analysis Approach is Threat-Based, Rigorous, and Quantifiable

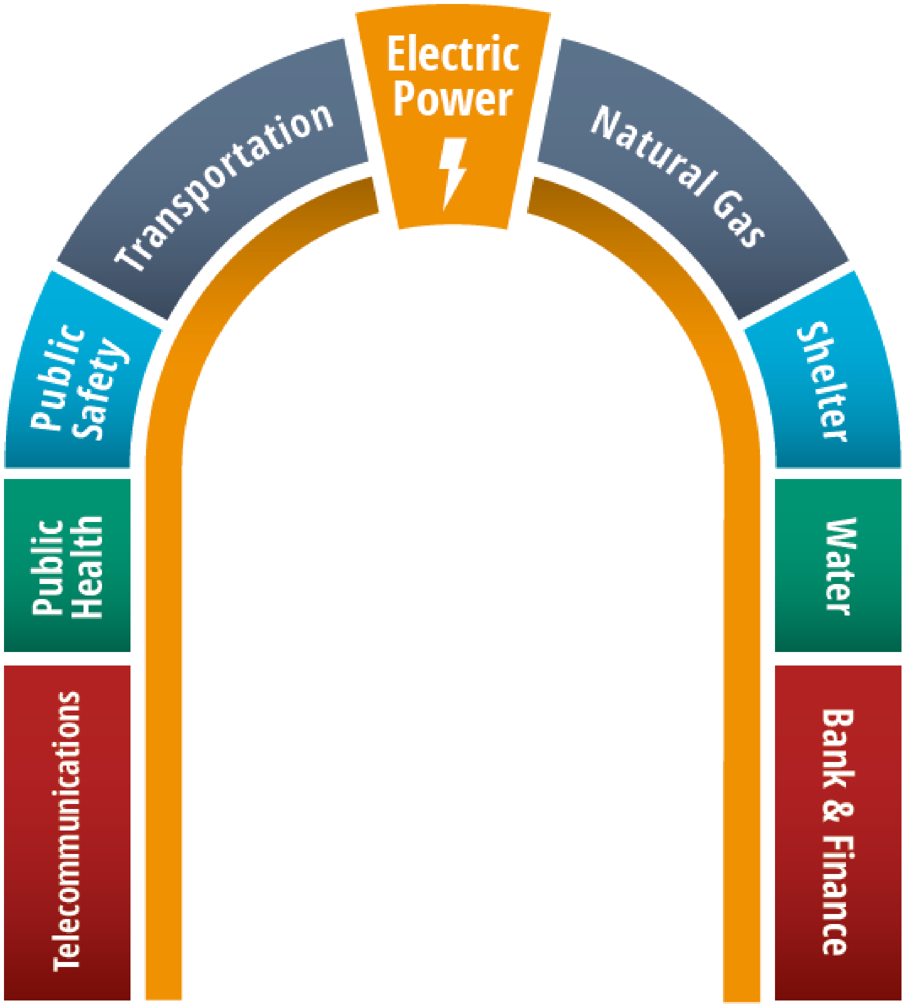








Energy Resilience Enables Community and Installation Resilience



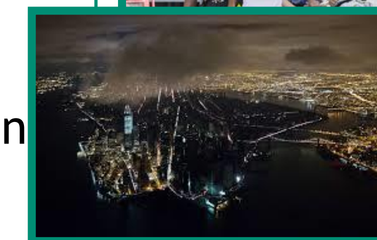
The grid is the keystone infrastructure – central to the web of interconnected systems that support life as we know it

Resilience and Reliability

Resilience

Includes ***low probability, high consequence*** events.

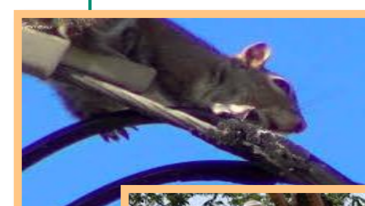
Not widely adopted. Still working on ***methods, metrics, and tools***



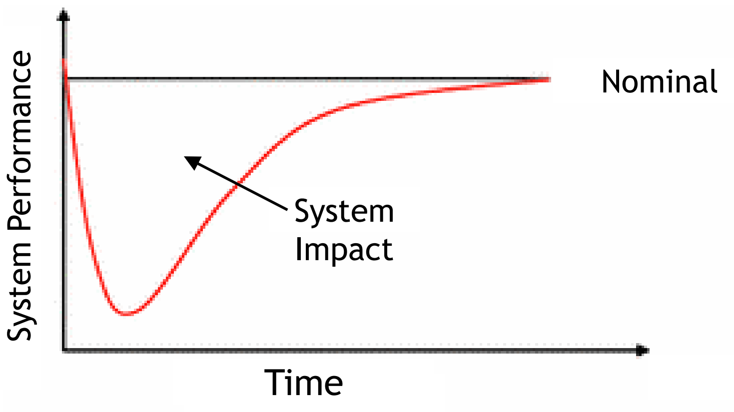
Reliability

Focuses on system performance with respect to **commonly expected events** (component failure, etc.)

Widely adopted for infrastructure investment decision-making



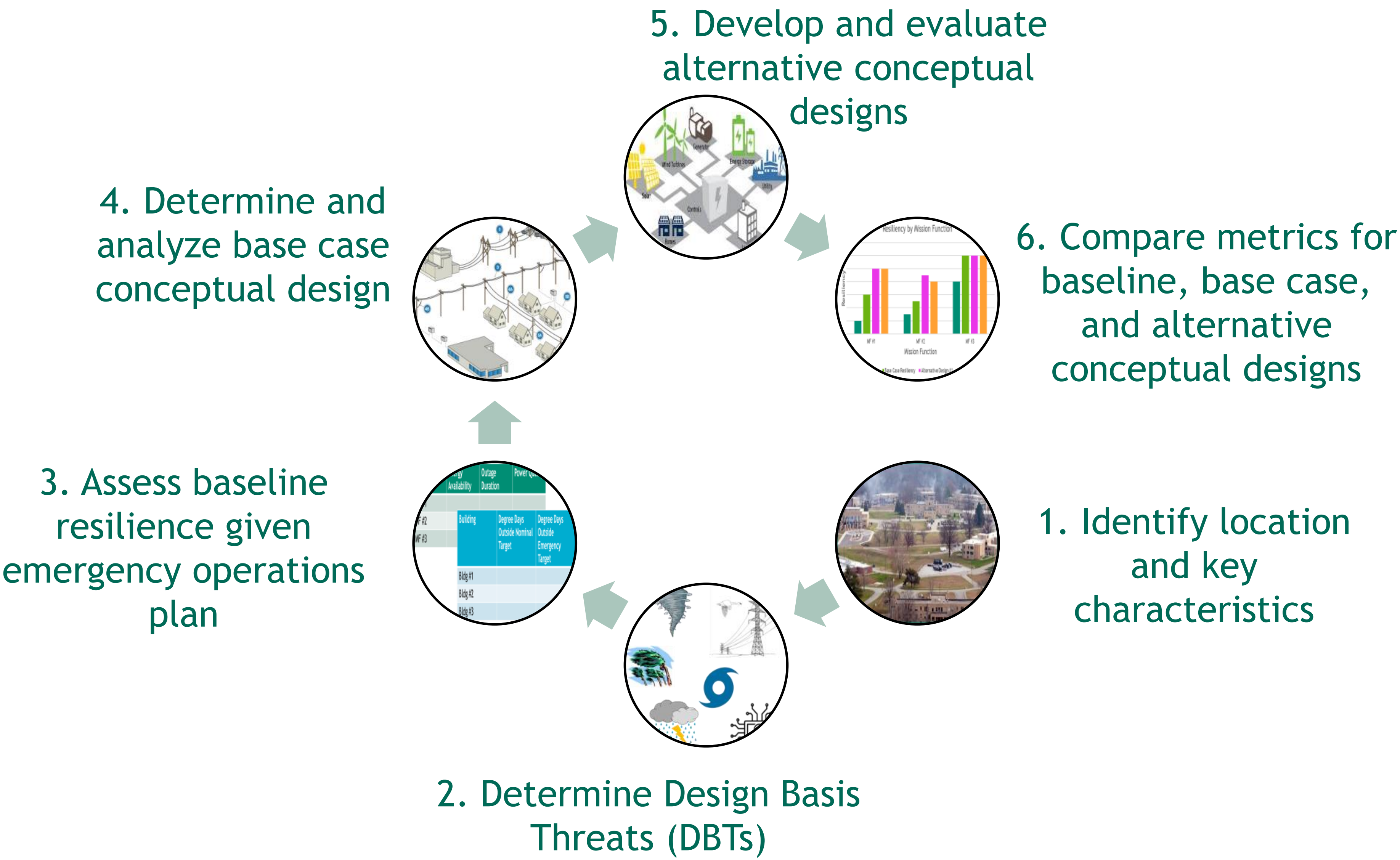
Defining Resilience



Ability to Prepare for, Withstand, and Recover from disruptions caused by major Accidents, Attacks, or Natural Disasters.

1. Resilience is contextual – defined in terms of threats or hazards
   - A system resilient to hurricanes may not be resilient to earthquakes
2. Includes hazards with low probability but potential for high consequence
   - Naturally fits within a risk-based planning approach…
   - …but difficult to capture this type of risk with high confidence

Resilience Planning Process



Step 1: Location and Key Characteristics

- Select location to be analyzed for resilience
  - Currently focusing on a framework that can be used for mid-size areas with simplified owner and funding situations such as:

Military Installations

Hospitals

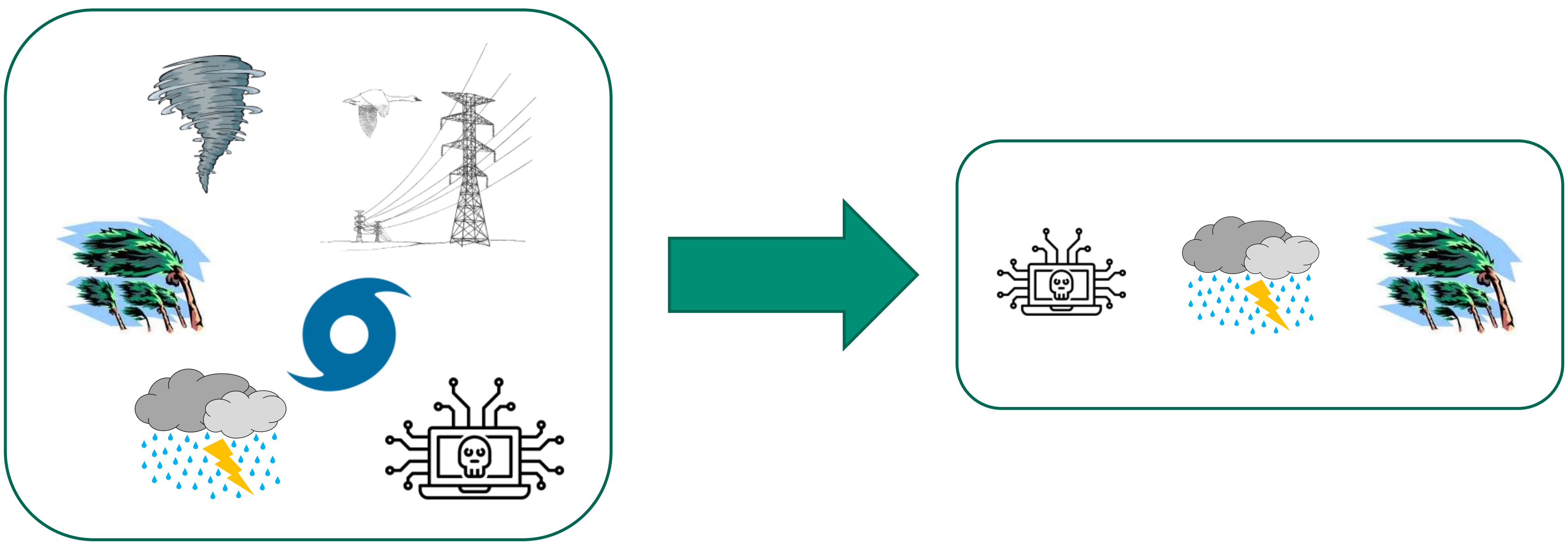
Campuses

Public Housing

- Understand key characteristics of the given location
  - One-source funding vs. multi-source funding
  - Single-owner vs. multi-owner

Step 2: Determine Design Basis Threats

- The resilience planning framework will include a detailed listing of various threat types and where to obtain more data on a specific threat
- Threats may be man-made, accidents, or natural disasters and should include probability distributions
  - Threat profiles should be at community level and then applied to buildings, distribution system, etc.
- For a given location, users must down-select from the master list of threats to a list that is specific to their area



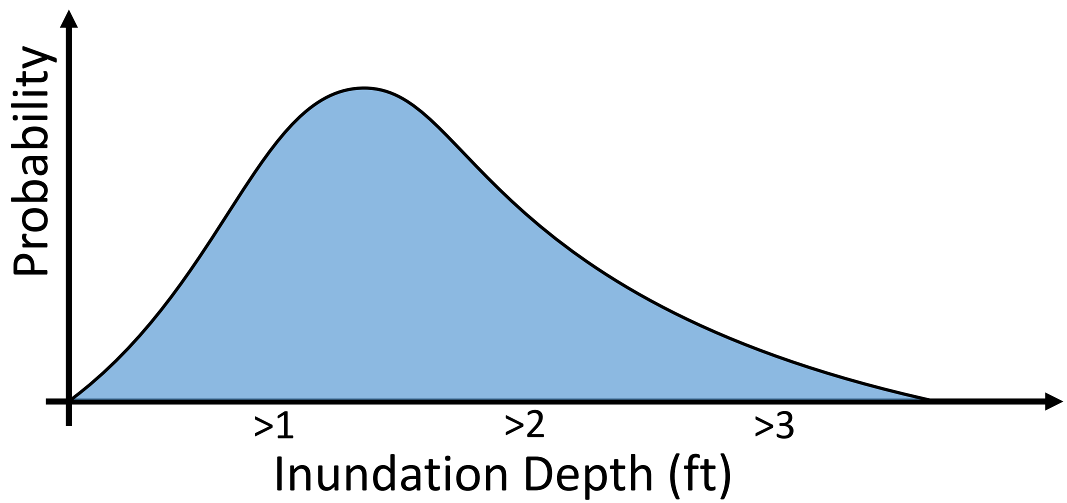
Master Threat List

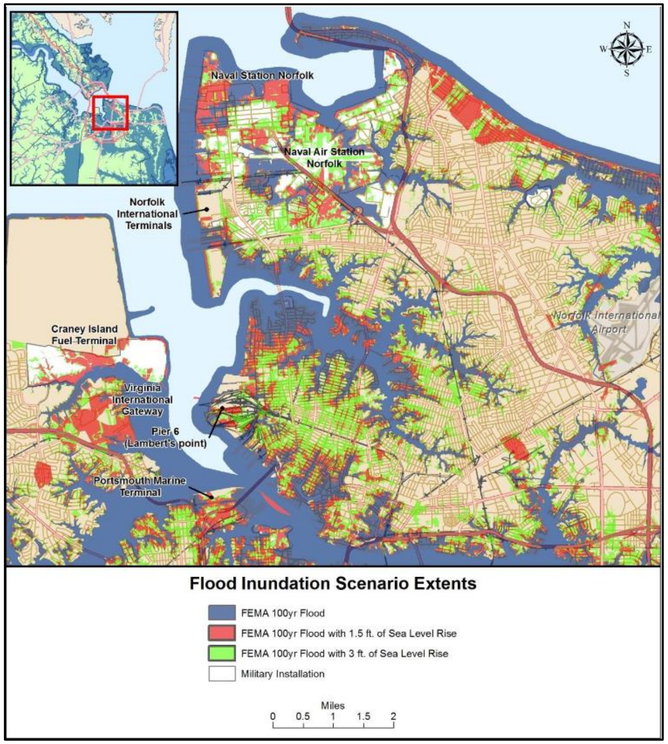
Local Threat List

Threat Characterization

- Need hazard magnitude (PDF or fixed probability) for each threat and location
- Probabilities may change over the planning horizon
- Want to be forward-looking so may need to use data with simulation model and project out to future years

Sources of Threat Data
- FEMA: inundation, wind, earthquakes, wildfires
- USGS: landslides
- NOAA: extreme heat, extreme cold, drought
- Sensor/record data

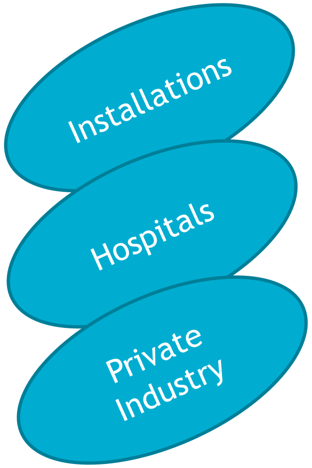




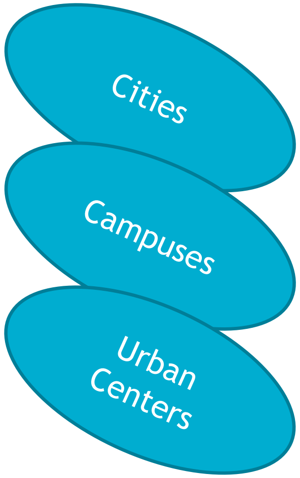
Threat distributions are needed for each threat type/combo and can be obtained from various sources

Step 3: Determine Appropriate Resilience Metrics

- Determine whether location is best served by operational resilience metrics or community resilience metrics
  - Operational resilience metrics: mission/function based
    - Ensure entity's ability to carry out critical missions/functions during and after an extreme event
  - Community resilience metrics: service based
    - Ensure members of the community have access to critical services during and after an extreme event



Example Mission Functions	Example Community Services
Computing	Food
Security Forces	Water
Emergency Services	Shelter
Surveillance	Medical Care
Communication	Restoration

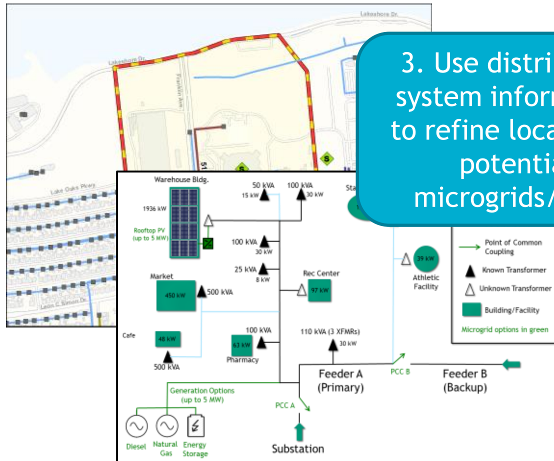


Will need to define either mission function or community service metrics for resilience analysis

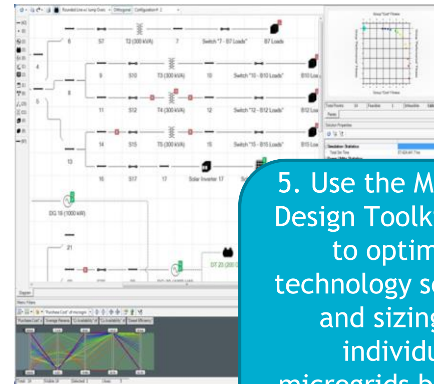
Example Community Resilience Approach

	Service 1	Service 2	...	Service n
Sector A		High		
Sector B	Low			
...				
Sector N		Low		Medium

1. Relate infrastructure points to critical services and determine level of service provided

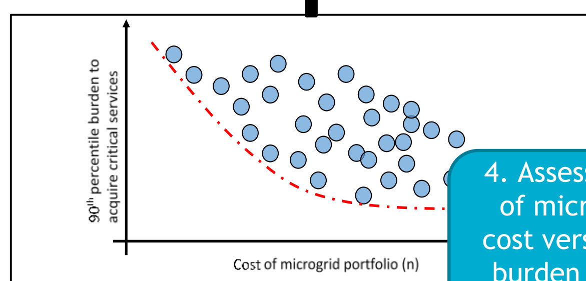


3. Use distribution system information to refine location of potential microgrids/DERs



5. Use the Microgrid Design Toolkit (MDT) to optimize technology selection and sizing for individual microgrids based on multiple metrics

2. Map out infrastructure points and existing energy supply infrastructure



4. Assess portfolios of microgrids for cost versus societal burden to acquire critical services

Step 3.1: Define Resilience Requirements

- To move beyond considering only the electrical system to a more holistic view of resilience, planners should determine mission functions or community services provided by the location and whether they are critical, priority, or other
  - Sandia's guidelines will include a comprehensive list of potential mission functions and community services, each of which can be expanded out into the various levels of criticality
  - Designs should always keep online buildings, systems, etc. associated with critical functions
- Functions/services and their criticality may be different in daily operations versus emergency operations
  - Use emergency plan to understand how usage will change in emergency situations
- Each mission function or community service must have defined requirements for metrics in the resilience matrices below:

Requirements

Mission Function	Required Energy Availability	Max Allowable Outage Duration	Min Allowable Power Quality
MF #1			
MF #2			
MF #3			

Mission Resilience Matrix

Service Type	Max Allowable Person Hours w/o Service	Max Allowable Burden to Acquire Acceptable Level of Service
Service #1		
Service #2		
Service #3		

Community Resilience Matrix

Step 3.2: Assess Resilience Metrics

- Based on the functions/services determined in step 3.1, calculate the baseline values in the resilience matrix
- For each thermal system needed to support mission functions, calculate the thermal system metrics for the building/system (degree days outside nominal and emergency targets)
- Metrics must be measured for each design bases threat/combination of threats

Mission Function	Energy Availability	Outage Duration	Power Quality
MF #1			
MF #2			
MF #3			

Mission Resilience Matrix

Baseline Metrics

Service Type	Person Hours w/o Service	Burden to Acquire Acceptable Level of Service
Service #1		
Service #2		
Service #3		

Community Resilience Matrix

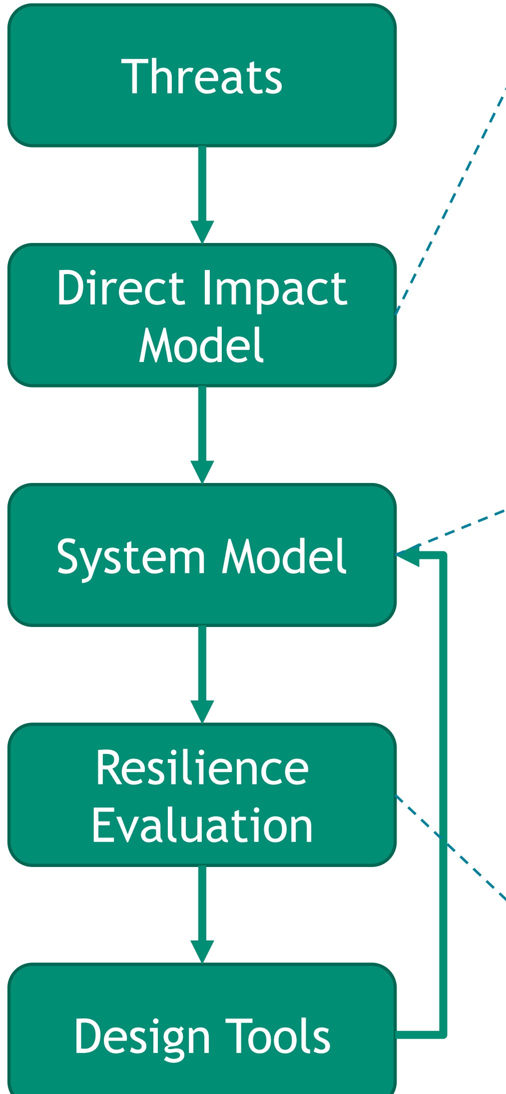
Gaps between baseline metrics and requirements must be addressed in base case and alternative designs

Step 3.2: Assess Resilience Metrics Cont.

Sample Tool Options

- Microgrid Design Tool (MDT)
- Resilient Node Cluster Analysis Tool (ReNCAT)
- System Master Planner (SMPL)
- Distributed Energy Resources Customer Adoption Model (DER-CAM)
- Renewable Energy Integration and Optimization (REopt)

Process



Data Needs

- Fragility curves
- Infrastructure points and properties

- Building loads (thermal & elec.)
- Building functions
- Spatial info
- Supply system models
    - Spatial (network model)
    - Physical (volts/amps)
    - Operational (control/protection)
        - Economic operations (heat rate, etc.)
        - Emergency operations (mitigation & recovery)

- Ways to achieve services/functions
    - M of n requirements

Step 4.1: Determine Base Case Conceptual Design

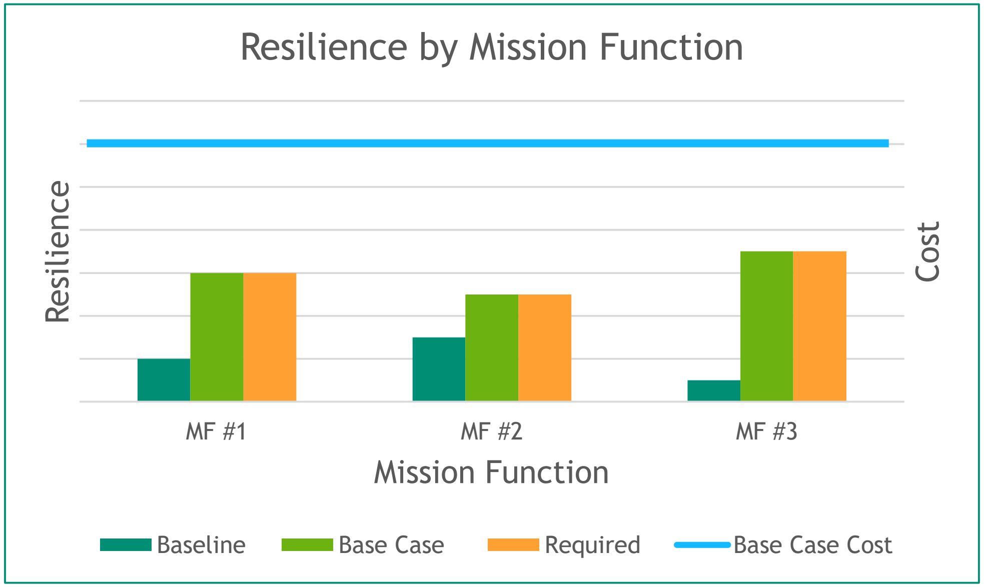
- The base case will be the first conceptual design made to improve resilience
- Solutions will include traditional technologies
- The base case conceptual design can be used to meet resilience requirements
- Sandia will provide a comprehensive list of traditional technologies appropriate for this step of the process

Example Traditional Technology Options

- Local backup boilers
- Local backup generators
- UPS
- Fuel storage
- Strengthen overhead lines
- Replace overhead lines with underground lines
- Add extra systems to ensure n+1 local redundancy

Step 4.2: Analyze Base Case Conceptual Design

- Once the base case conceptual design is complete, compute all resilience metrics in the mission resilience matrix or the community resilience matrix
- Compare base case resilience metrics to baseline resilience metrics
- Base case must meet resilience requirements
  - Meeting requirements may lead to high costs when using off-the-shelf technology options, particularly if including n+1 redundancy



Base case design meets resilience requirements but may have high costs

Step 5.1: Determine Alternative Design(s)

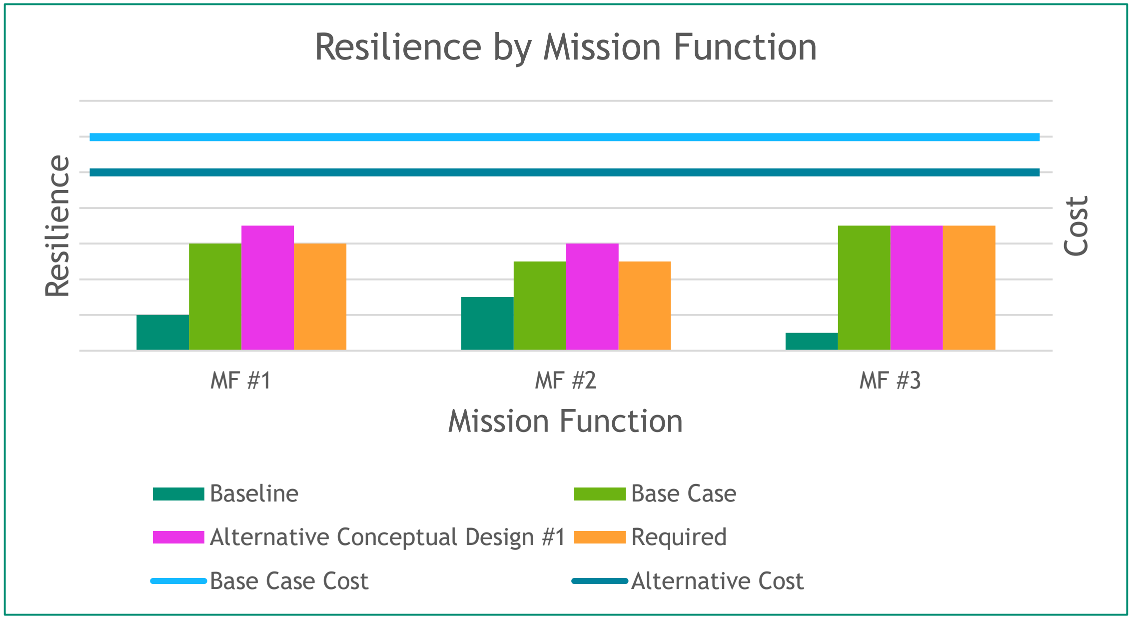
- Alternative designs will be developed to further improve resilience and/or decrease the cost as compared to the baseline and base case designs
- Solutions will include state-of-the-art technologies, and potentially optimal technology selection and placement within the system
- Sandia will provide a comprehensive list of state-of-the-art technologies appropriate for this step of the process

Example State-of-the-Art Technology Options

- Hot water and low temperature DH networks
- High temperature district cooling networks
- Efficient heat pumps
- Combined cooling, heat, and power (CCHP) with ad-/absorption cooling systems
- Power-to-heat
- Electrical and thermal storage systems
- Microgrids
- Waste heat
- Regenerative technologies

Step 5.2: Analyze Alternative Conceptual Design(s)

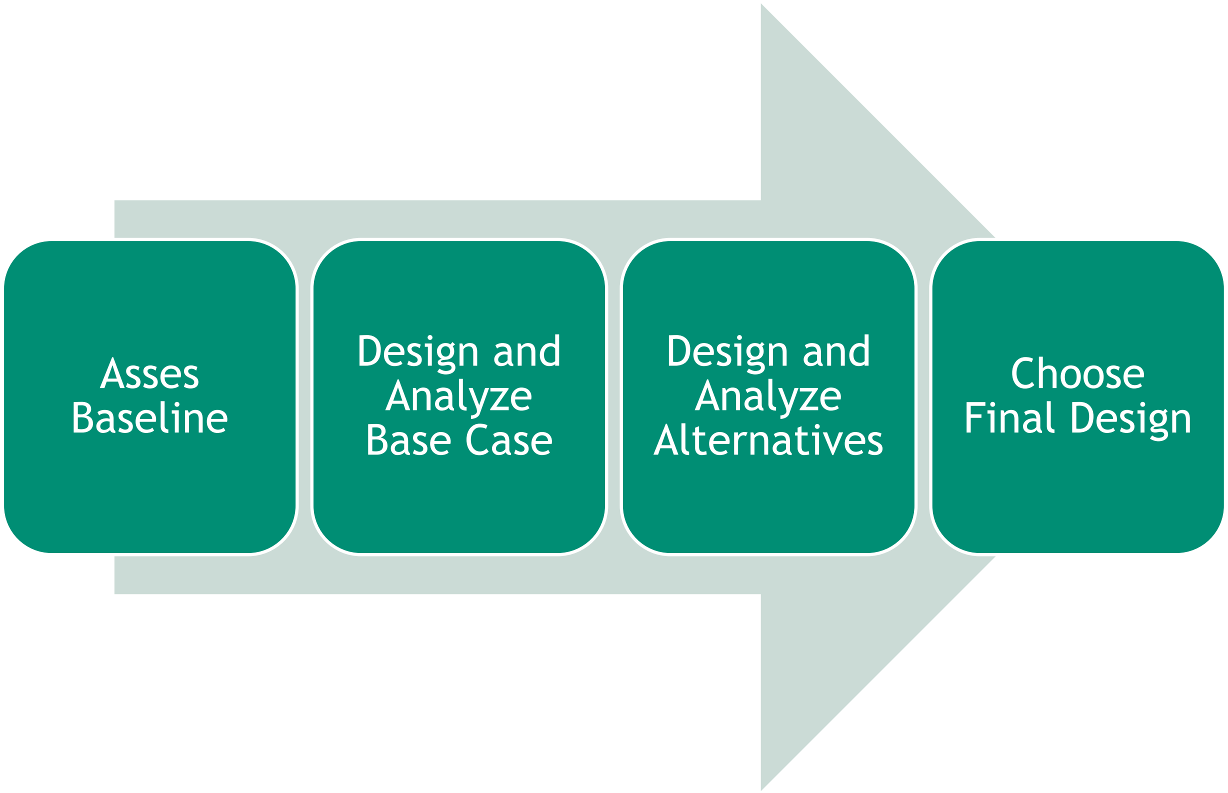
- Once the alternative conceptual design(s) is complete, compute resilience metrics in the mission resilience matrix or the community resilience matrix for each alternative design
- Compare alternative design resilience metrics to baseline and base case resilience metrics for each alternative design
- Also compare the resilience metrics of each alternative design to the required resilience metrics



Alternative designs use new technologies and/or optimization to meet or exceed resilience requirements while minimizing cost

Step 6: Select Design

- After the baseline, base case, and all alternative options have been designed and evaluated, select desired design based on comparison of metrics
- Selected design becomes guideline for A&E firm

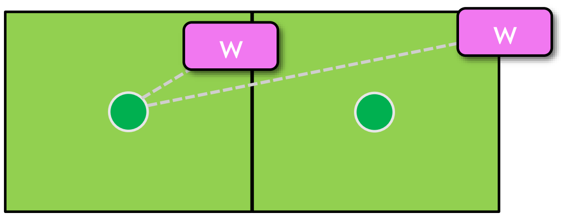


Backup

Decreasing Social Burden through Microgrids

Metrics of social burden:

- Effort required for people to satisfy their needs, divided by their overall ability
- Can be decomposed by different needs: shelter, food, water, etc.
- Can be discretized by city zone, district, census block, etc.



$$B_C = \sum_{inf} \sum_{pop} \frac{E_{inf,pop}}{A_{pop}}$$