INCORPORATING RESILIENCE AS A GOAL WITHIN ENERGY MASTER PLANNING

PRESENTED BY

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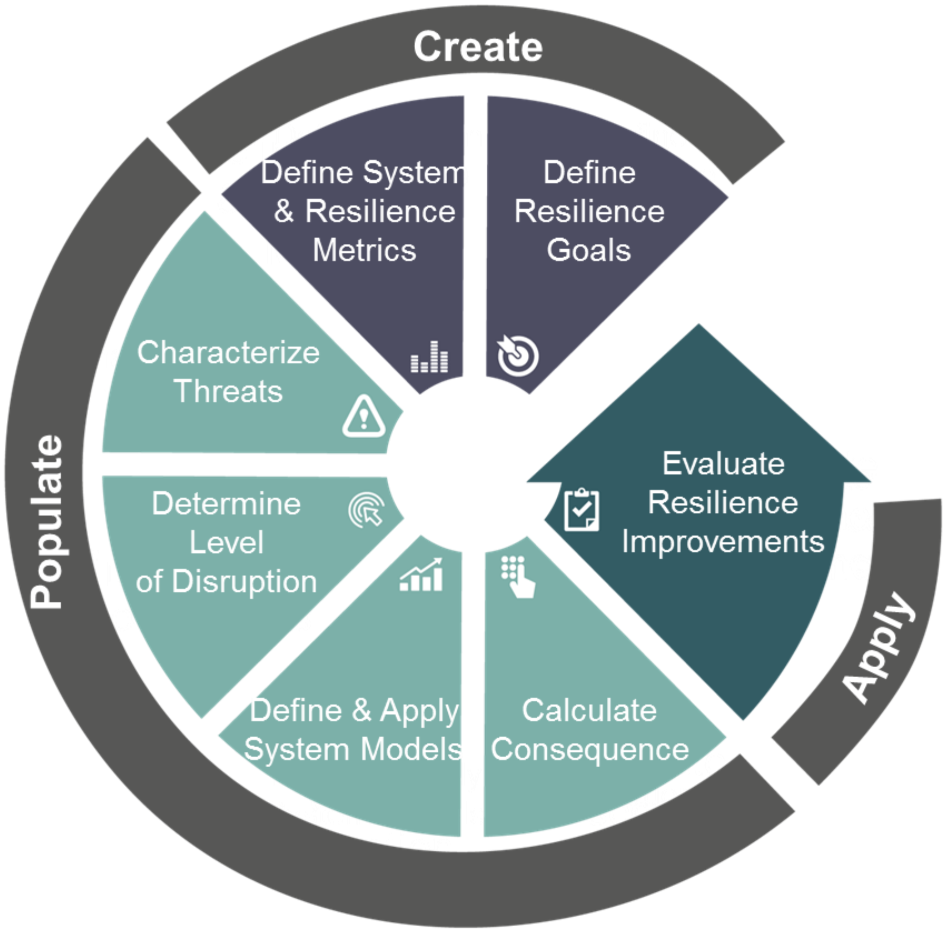
A GENERIC FRAMEWORK FOR PLANNING



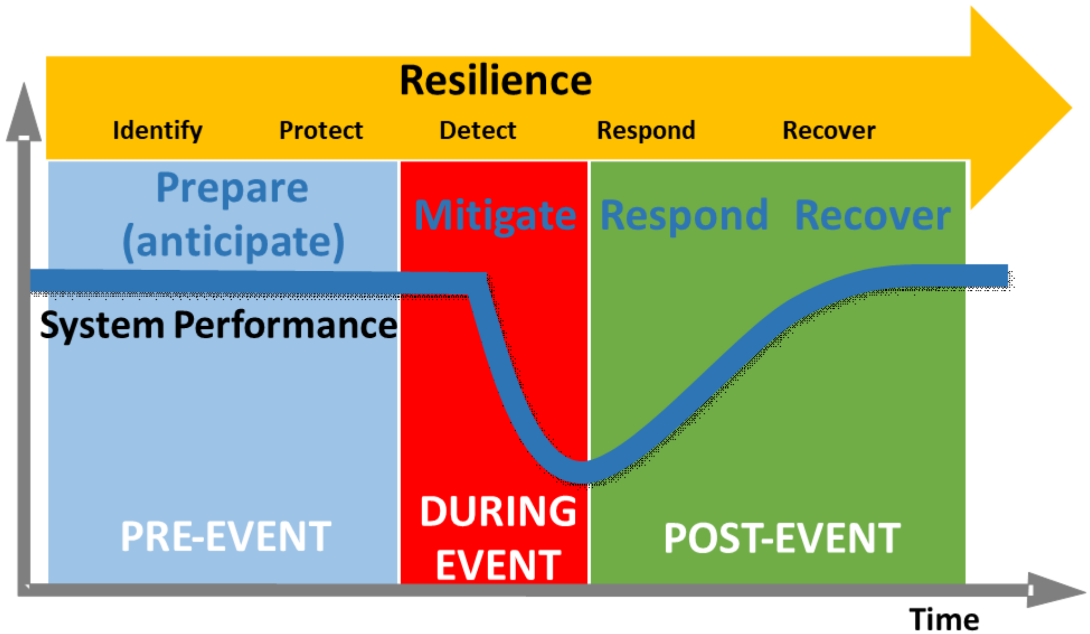
Resilience planning framework developed for the 2014 Quadrennial Energy Review

Simplified:

- Determine performance-based metrics
- Populate metrics for the do-nothing baseline
- Evaluate alternatives against those metrics

Because we are talking about resilience, it becomes more complicated

ENERGY RESILIENCE DEFINED



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

A resilient energy system <u>supports critical community functions</u> by preparing for, withstanding, adapting to, and recovering from disruptions.

DEFINING RESILIENCE GOALS, THE SYSTEM, AND METRICS

1. Begin by asking the question:

   - **What keeps you up at night? -OR-**
   - **How do you define a really bad day?**

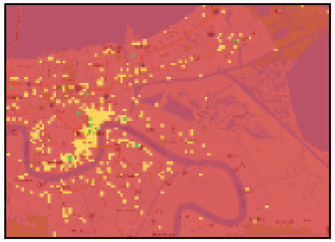
   - The answer to this question will define threats, categories of consequence, and the systems of highest importance

<u>Norfolk, VA</u>

- A nor'easter that inundates the city with rain and tidal surge, limiting ability to keep globally-connected assets operational
- The possibility that others don't see value in keeping Norfolk resilient

<u>New Orleans, LA</u>

- A high cat 2, low cat 3 hurricane in which we don't evacuate, and it drops nearly a meter of rain
- Thousands of people displaced, without shelter and primary services such as food, water, shelter, and medical care

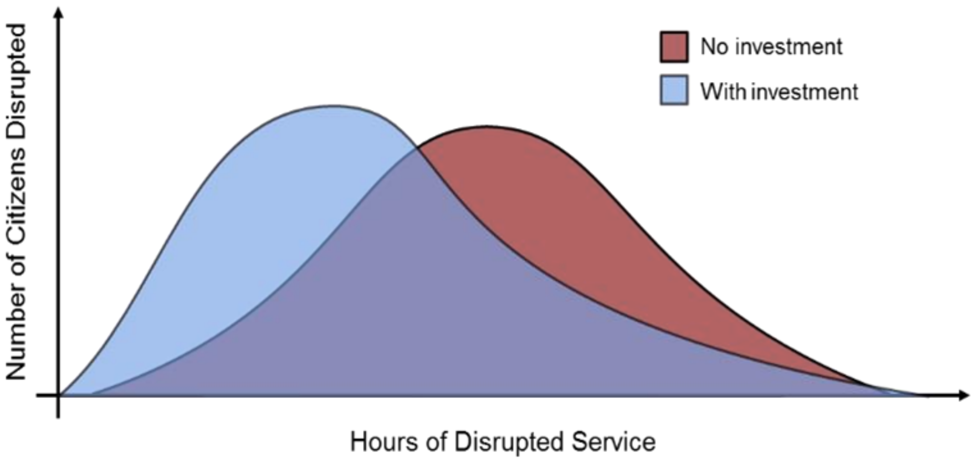


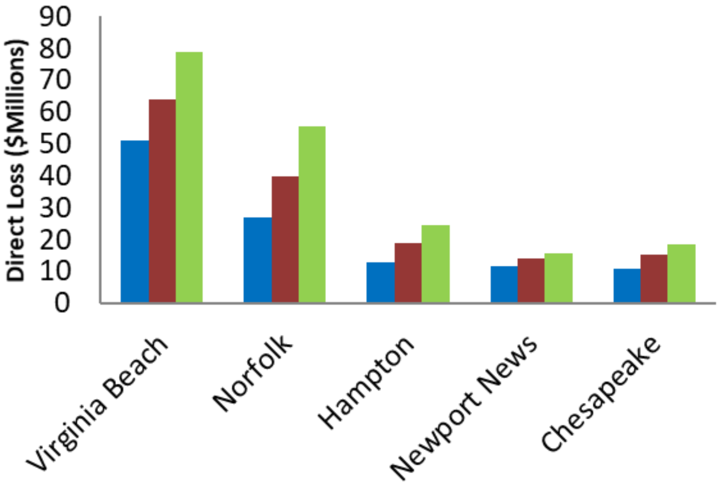
As an energy system planner, what keeps you up at night?

OPTIONS FOR METRICS OF CONSEQUENCE

Three categories of consequence-focused resilience metrics

1. Economic
   - Gross municipal product
2. Societal
   - Citizens without access to lifeline services
3. Mission-focused
   - Likelihood of serving mission-critical loads





Not necessary to only choose one category

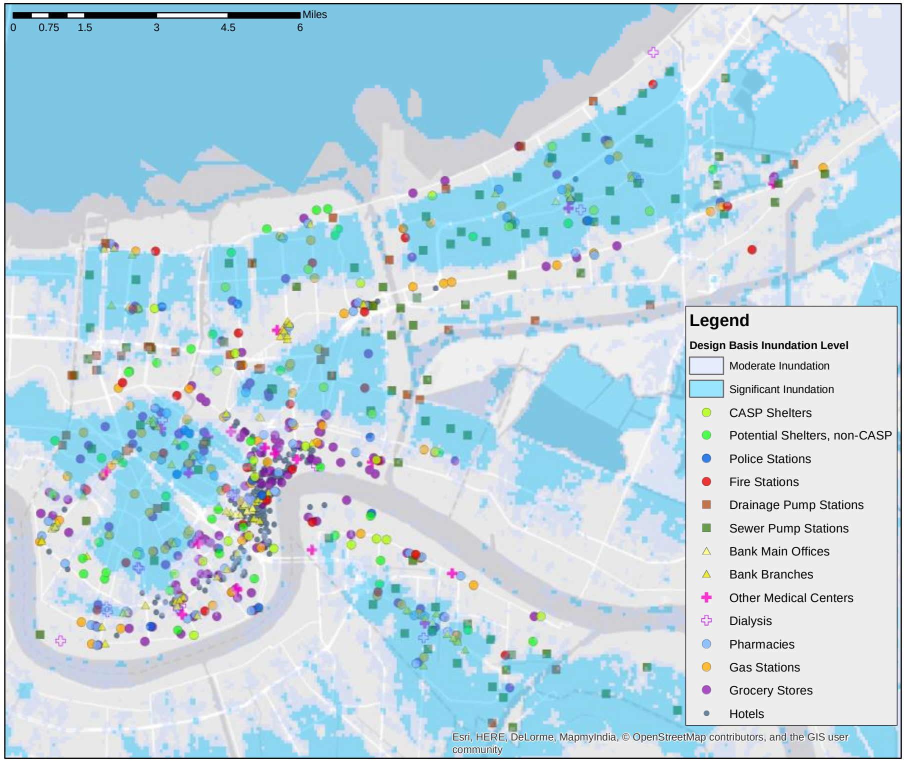
RELATING LOADS/ASSETS TO CONSEQUENCE

"Lifeline" Infrastructure Services

Electric Power	Entergy, SWBNO	Food	Commercial, PODs
Drinking water	SWBNO, PODs	Emergency Response	Police, Fire, 911
Dewatering	SWBNO	Communications	
Sewerage	SWBNO	Finances	
Medical Services	Hospitals, Pharmacies	Transportation	
Shelter	City shelters, Schools		

Output of this step:

1. A table of targeted electrical performance for each critical asset
2. A functional relationship between each asset and the consequence-based metric
3. A map of all assets



Which assets are most critical to providing each function?

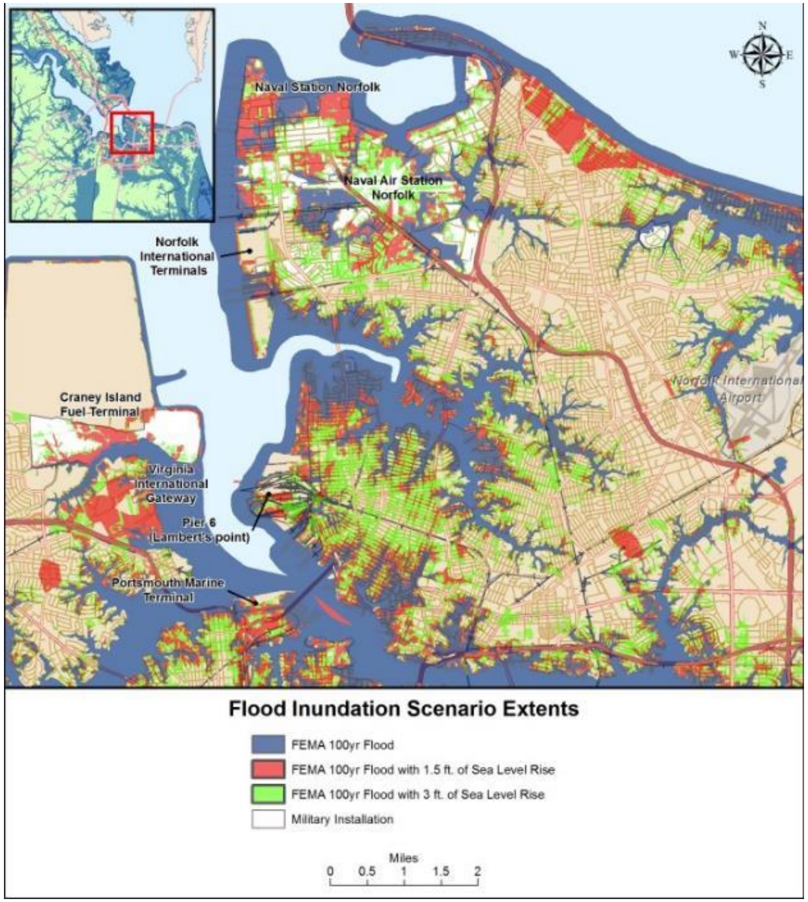
How critical is electricity to these assets?

CHARACTERIZING THREATS

Over your planning horizon, what level of disruption is likely to occur, at what probability?

Example: Norfolk, VA

- Fastest net sea level rise in North America
- Many projections have 1 foot by 2050 and 3 to 4 feet of net SLR by 2100
- We used geospatial modeling techniques to extrapolate a dynamically rising 100-year flood against a dynamically sinking digital elevation model
- Results in 3 snapshots (2015, 2050, 2100) at a constant probability
  - Feasible to interpolate between these snapshots



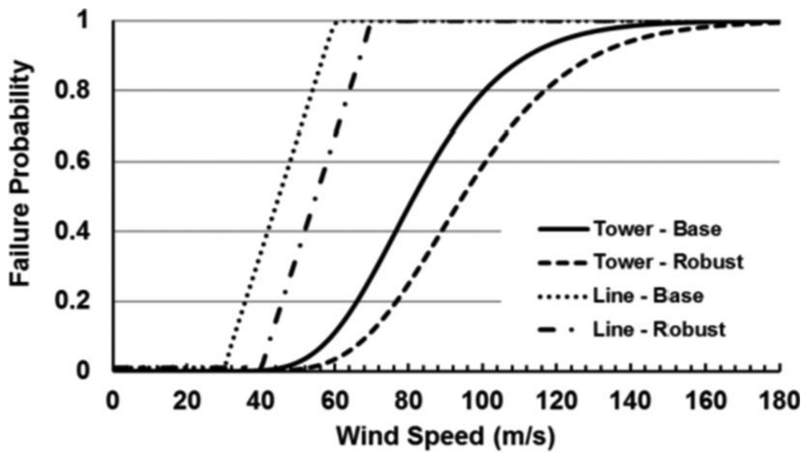
Characterize the threat by analyzing the probability of effects spatially and temporally

DETERMINE SYSTEM PERFORMANCE (BASELINE)

Without any improvements, how does your energy system and its dependent systems perform?

Analysis Method: Fragility Curves

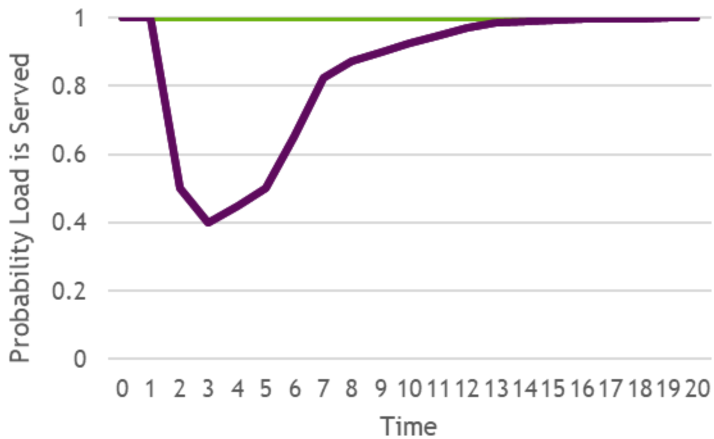
- Estimate probability of failure at various levels of threat effects
- Naturally lead to probabilistic modeling
- Other dimensions:
  - Age of equipment
  - Time exposed to threat



INPUT

Analysis Method: System Models

- Sample over the failure probabilities to generate probability of each load being served (through time)

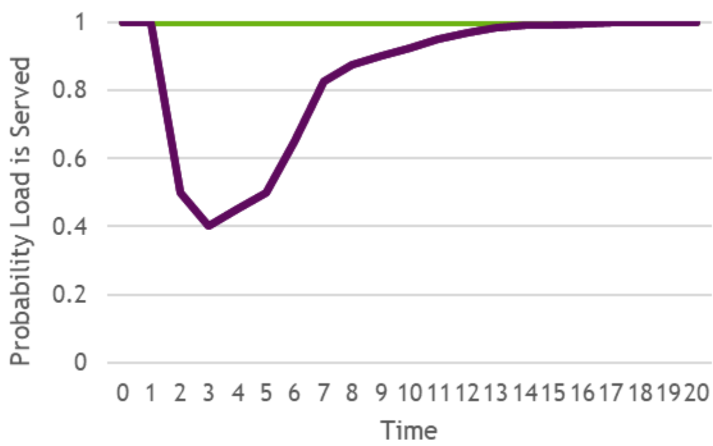


OUTPUT

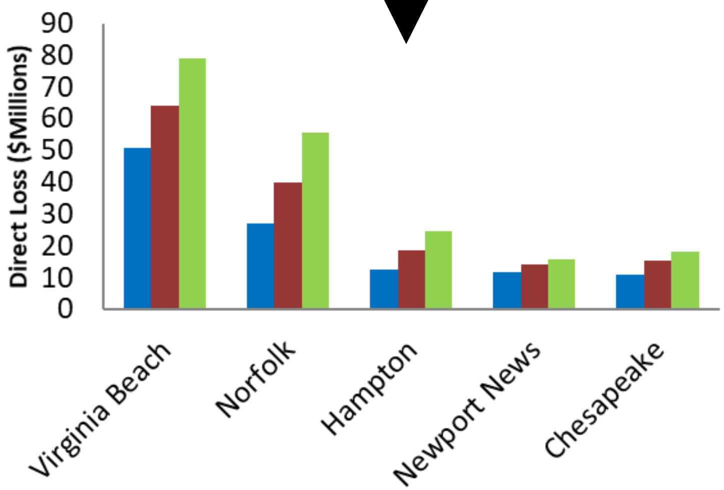
Output of this step is probabilistic energy performance through time at each critical load

ESTIMATE CONSEQUENCE (BASELINE)

Without any improvements, what is the projected consequence to your system?

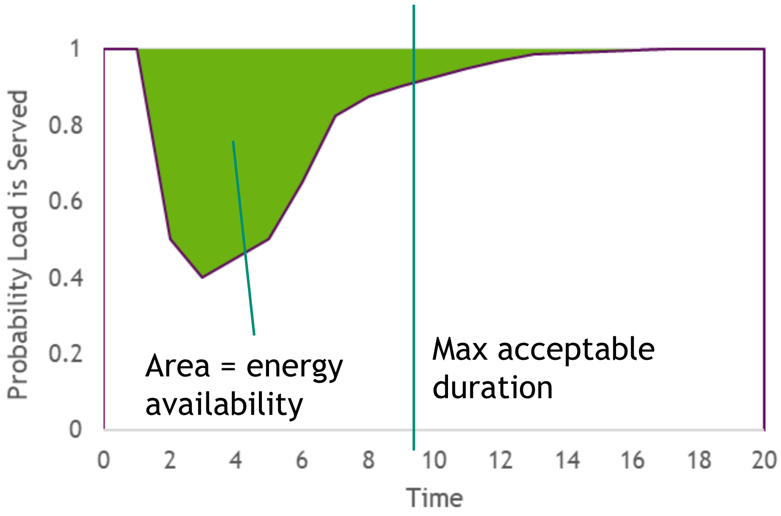


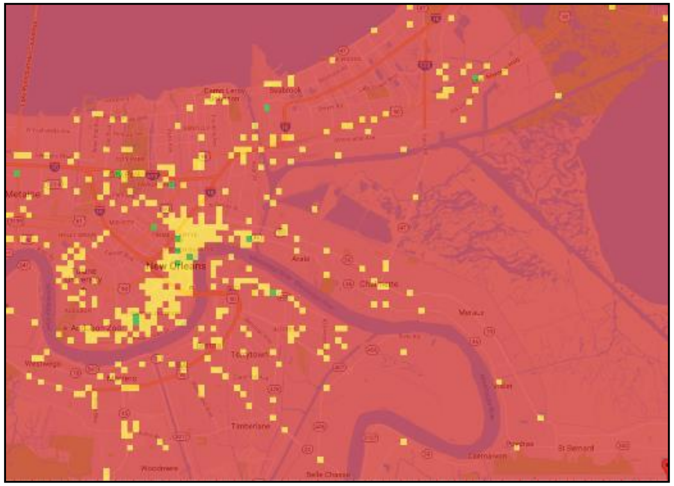
Functional model that relates economic consequence to individual asset performance



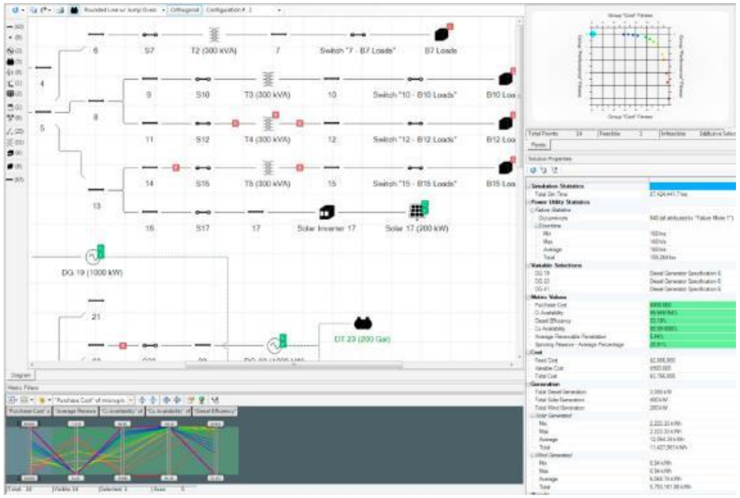
Output of this step is estimate of probability vs. consequence, or estimate of expected consequence over the planning horizon

DESIGN ALTERNATIVES





ReNCAT (Resilient Node Cluster Analysis Tool)



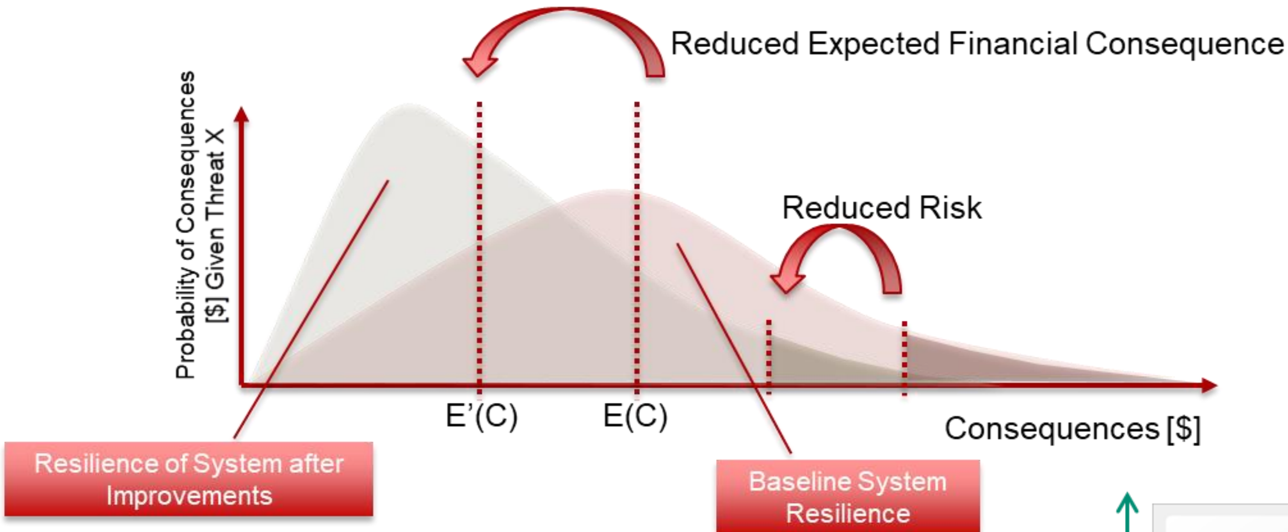
MDT (Microgrid Design Toolkit)

Use engineering principals and tools to design different alternatives to meet resilience requirements

- Start at most critical loads and work down – BUT – design the system, not the building
- Keep day-to-day goals in mind

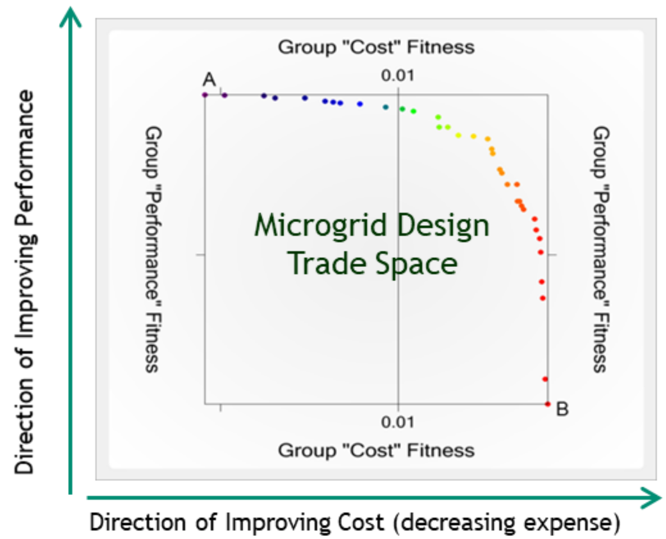
There are two options at this step – Design for islanded performance alone, or design for islanded + grid-tied operation

EVALUATE ALTERNATIVES BY COMPARING METRICS



Run models for system performance and consequence again with the design alternatives

- Output is a distribution of probability vs. consequence for each alternative
- Can evaluate the mean, the conditional value at risk, and other distribution properties
- Pareto efficient frontiers can help filter options



At times it is difficult to evaluate based on a single metric. Multi-criteria decision making techniques exist

PATH FORWARD

For Annex 73

- Agreement with the process?

- How much of the process should be incorporated into the Task E tool?
  - contain fragility curves and threat characterizations – OR
  - start with probability of failure as an input?

  - Optimize for resilience, then add to system to optimize for blue sky benefit – OR –
  - Co-optimize for resilience and blue sky benefit – OR –
  - No optimization, only estimate performance based on design?

- Which partners have capability and interest in which stages of this process?

Thank you!

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