DOE Resilient Smart Grid Activities

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Smart Grid R&D Program

Modernizes distribution grid through advanced ICT and new operational paradigms (microgrids and transactive controls)

Supports increasing demand for renewable energy integration and grid reliability and resiliency at state and local levels

FY 2014 and Prior

- **Microgrids**
- DER/DR/PEV Integration
- Distribution Automation

FY 2015/ FY2016

- **Microgrids**
- **Resilient Distribution Grid**
- Transactive controls
- Advanced Distribution Management System

Smart Grid R&D Focus Areas

Microgrid R&D

For commercial viability, reliability, and resiliency

Continue R&D pathway to support achieving the DOE program goals (in reliability, efficiency, CO_2 reduction, and cost effectiveness) and implementing the DOE CAP strategy, leading to creating a smarter and more resilient grid and community.

Advanced Distribution Management System (ADMS)

Providing better control and visibility

Develop architectures that integrate new & existing applications across the utility enterprise to accommodate rapid and complex communications/interactions between D&T; develop operational control strategies using advanced analytics.

Resilient Electric Grid R&D

For enhanced grid resilience

Implement high-priority R&D projects identified in the resilient grid roadmap, developed in a broad stakeholder workshop in 2014 and finalized during the QER in 2015.

Market-Based Control Signals

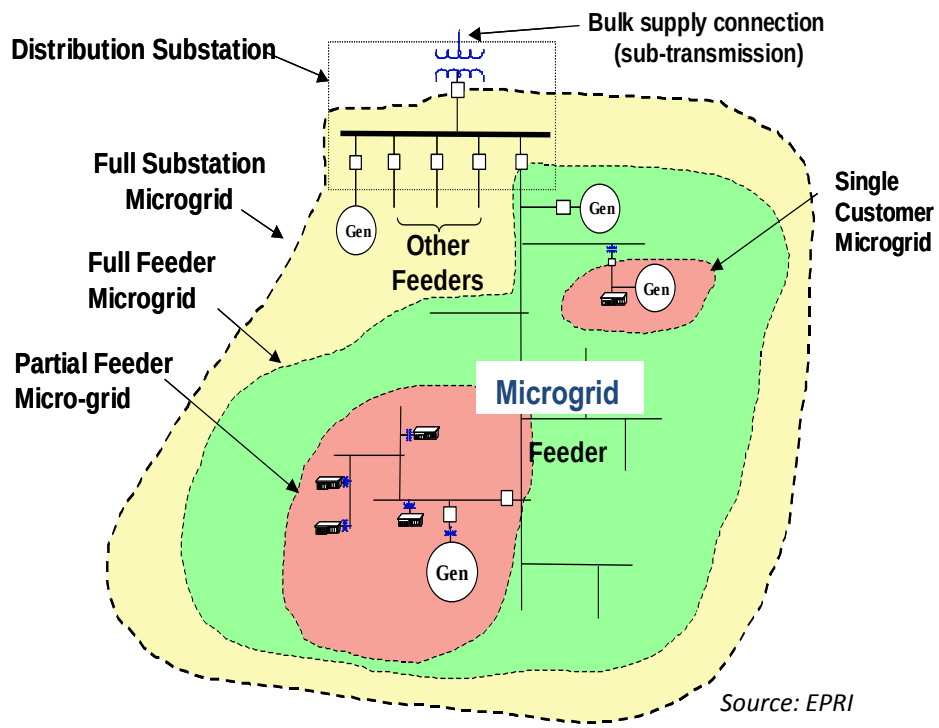
Enabling economical and flexible stability

Develop simulation tools for the impact of transactive control, establish valuation basis for customer-delivered and grid-delivered energy services, and assess how to achieve a more distributed customer-driven grid.

DOE Program's Definition of Microgrids

Our definition:
A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in grid-connected or island mode.

Residential	Less than 10-kW, single-phase
Small Commercial	From 10-kW to 50-kW, typically three-phase
Commercial	Greater than 50-kW up to 10MW



Source: EPRI

Energy Surety Microgrid Design Concept by Sandia

When utility power is unexpectedly lost, normal backup operations occur (ESM does not preclude traditional, accepted engineering practice)

During outage, UPS carry non-interruptible critical loads as microgrid disconnects from utility and diesels start

Architecture reconfigures existing medium voltage (MV) network to create a microgrid backbone

Connections for existing diesels are changed to allow simultaneous connection to critical building loads and also MV network (additional energy assets can be added, but ESM does not require new central plant)

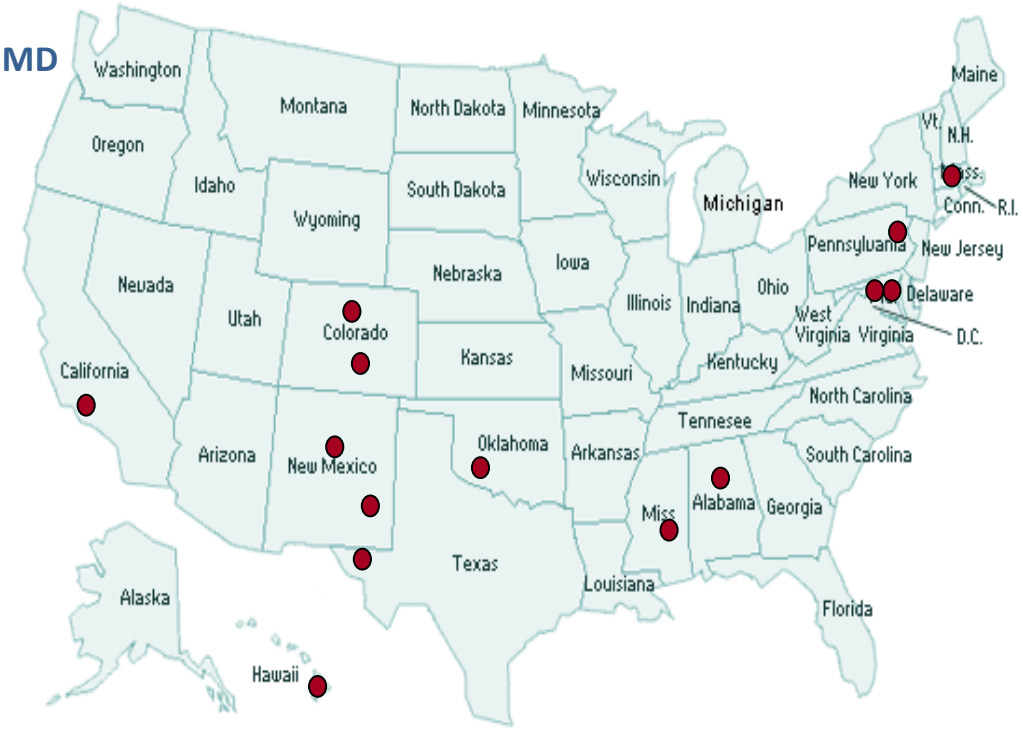
Diesels are synched together on MV microgrid network, and any other additional sources (like renewable energy) are brought online

Tier 2 loads may be served as feasible and useful

ESM reuses existing equipment to support mission energy security

Energy Surety Microgrid Assessments & Conceptual Designs with DoD

- Ft. Belvoir, MD – 300 Area
  - Developed eight conceptual designs; working with DoD on partial implementation
- Maxwell AFB, AL (R&D project)
  - Designed and supervising construction as experimental microgrid
- Ft. Devens, MA, 99th ANG
- Indian Head – Naval Surface Warfare Center, MD
- Ft. Sill, OK
  - Developed ESM design including 700-1000 kW landfill gas distributed generation system
- Kirtland AFB, NM
  - Eight ESM conceptual designs complete
  - supporting collaborative DoD/DOE proposals for further development and implementation
- Ft. Carson, CO (SPIDERS site)
- Camp Smith, HI (SPIDERS site)
- Ft. Bliss, TX
  - Multiple ESM designs complete
- Vandenberg AFB, CA
- West Point, NY
- Cannon AFB, NM



Smart Power Infrastructure Demonstration for Energy, Reliability, and Security (SPIDERS)

SPIDERS is building three microgrids, each with increasing capability, which will function as permanent energy systems for their sites

- Site 1 (Joint Base Pearl Harbor Hickam) is complete
- Site 2 (Fort Carson) is complete
- Site 3 (Camp Smith): completed preliminary design, demo in FY15

Project will promote adoption of microgrid technology for DoD through:

- Design and requirements methodology
- Cyber security architecture

Sponsored by:

PACOM NORTHCOM DOE DHS

Commercial Applications for ESM to Help Communities as They Prepare for Climate Impacts

NJ TransitGrid Project

- Microgrid to enhance grid-rail resiliency to serve over 900,000 riders/day
- Key evacuation service for Manhattan & N. New Jersey
- MOU between DOE and State of NJ
- **Completed the feasibility study; received the FTA award in Sept 2014 to build microgrid**

Hoboken ESDM Project

- Provide electrical power to support critical functions up to 7 days for 52,000 residents in 1.2 sq. mi.
- Key evacuation route for Manhattan
- DOE-Hoboken-BPU-Sandia-PSEG Partnership
- **Completed microgrid conceptual design for Hoboken, NJ, to enhance system resilience post-Sandy**

CERTS Microgrid Controller

Santa Rita Jail

CERTS Microgrid

No critical load outages since dedication 3/22/2012

"The CERTS Protocol is a powerful tool for integrating distributed generation resources."

Brevoort Co-op, Manhattan

"*CERTS microgrid-cogen system from Tecogen comes through for Greenwich Village Co-op building during superstorm Sandy.*"

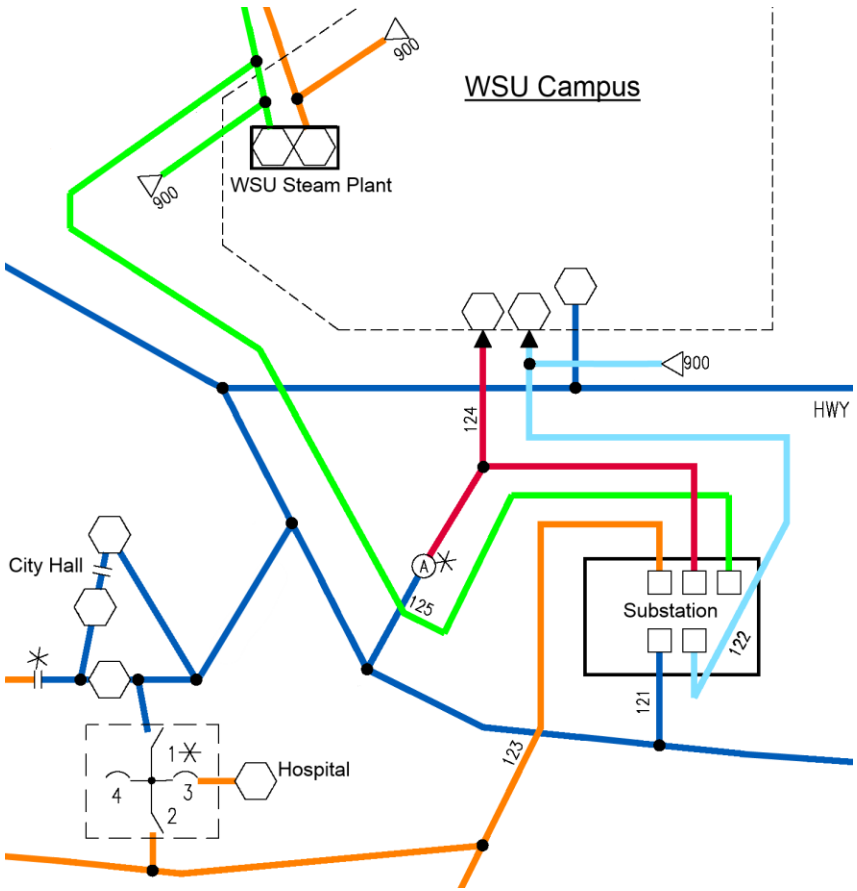
"The CERTS microgrid control technology is the most radical of all options-as well as the lowest cost-as it is embedded into a 100-kW CHP system offered by Tecogen."

Peter Asmus, Navigant.

Microgrids as a Resiliency Resource

Demonstrate feasibility for microgrids to enhance distribution systems by serving critical load and strengthening fast recovery capability following major outage

- PNNL/WSU developed dynamic system model for WSU-Pullman microgrid being used to evaluate dynamic impacts on switching, protection, and motor controllers
- Conducting dynamic simulations to have microgrids reduce number of switching operations during restoration
- Using capability of microgrids to pick up more interrupted load



Industry-Led Microgrid R, D & System Design

FY 2014 FOA

- **Advance microgrid system designs (<10MW) and control functionalities for implementation by communities to support achievement of:**
  - **Communities-defined resilience objectives**
  - **DOE program targets**: reducing outage time of critical loads by >98%; cost comparable to non-integrated baseline solutions (UPS + diesel genset); reduce emissions by >20%; improve system energy efficiencies by >20%
- **FOA selections announced on 8 Sept**
  - **$8M DOE funding for 7 awards** ($1.2M per award)
  - PoP: 2 years, including 18-month R&D and 6-month **testing, data collection, and analysis**
  - **Awards NLT than end of September 2014**
- **Field demonstrations of system designs w. advanced controllers** (potential FOA topic in FY16-17)

Microgrid R&D Timeline

2009 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021

Niche Applications
- >15% Peak load reduction
  (Renewable and Distributed Systems Integration)
- Military (energy surety microgrids & SPIDERS)

Planning & Design
- Microgrid Design Toolset (MDT)
- Commercial applications of ESDM
  (states and regions)

Control, Coordination, & Protection
- Grid-interactive controller (steady state & transient)
- FY14 FOA projects (meet DOE targets/resilience)

Operational Optimization: Single Microgrid
- DC microgrids
- Field demo of down-selected FY14 FOA projects
  (commercial viability)

Operational Optimization: Multiple Microgrids
- Networked microgrids
  (AC only, DC only, and AC/DC hybrids)

Resilient Electric Distribution R&D: A New Focus Area

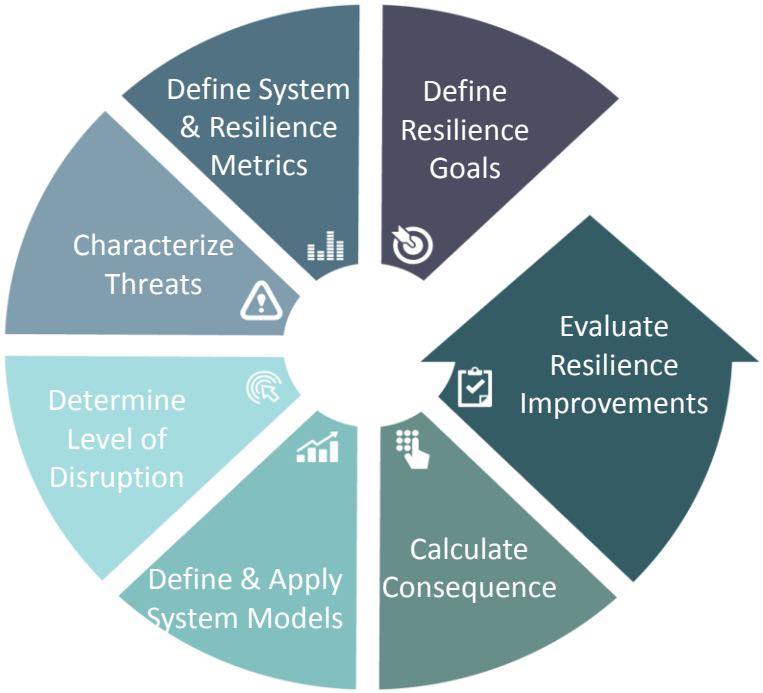
Implement the Resilient Grid Roadmap to accomplish 20% reduction in systemic impact (calculated from outage duration and frequency and avoided lost load value) under extreme weather scenarios; goal target will be set with feedback from stakeholders during 2015 QER

Enhanced System Design	Preparation & Planning	Operational Response	System Repair and Recovery
• Design tools that integrate existing modeling modules (e.g., from NISAC) for use by distribution utility designers for rebuilding & upgrades	• Geospatial power system modeling tools with weather forecasting for damage prediction and response	• Advanced analytics for operational decisions • Novel control algorithms driven by all-hazards impact assessments	• Integration of grid modeling with optimization algorithms to promote evaluation of options for repair and recovery in near real-time

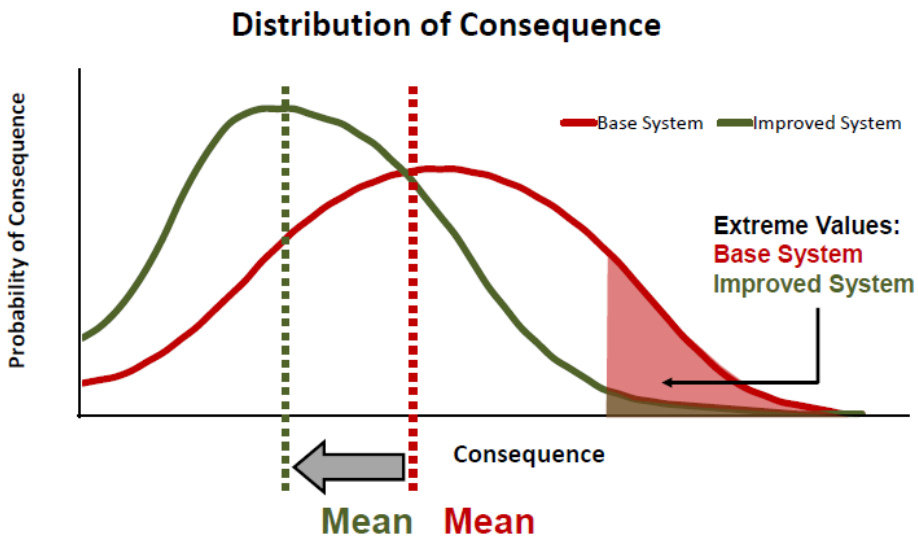
Work elements will be in full alignment with Resilient Grid Roadmap developed in 2014 (framework) and finalized during 2015 QER

Framework for Developing Resilience Metrics

Resilience Analysis Process:
How metrics should be defined and used



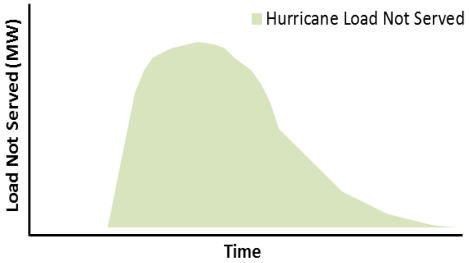
Resilience Metric:
Used to compare performance of improved system vs. baseline



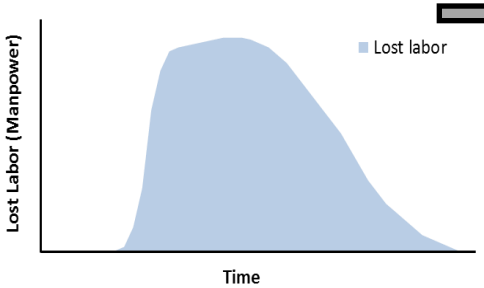
Framework for Developing Resilience Metrics

Performance Indicators

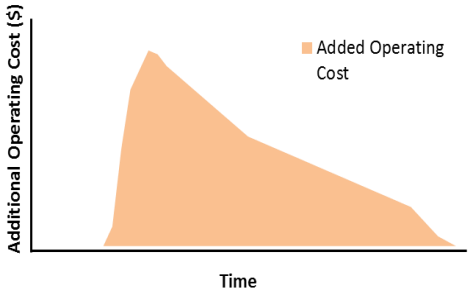
Load Not Served, Hurricane



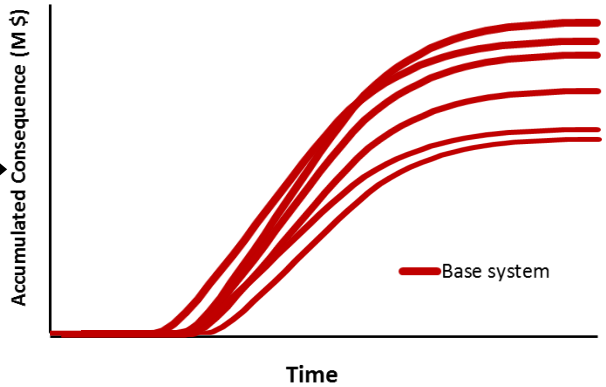
Decreased Labor, Hurricane



Added Operating Cost, Hurricane



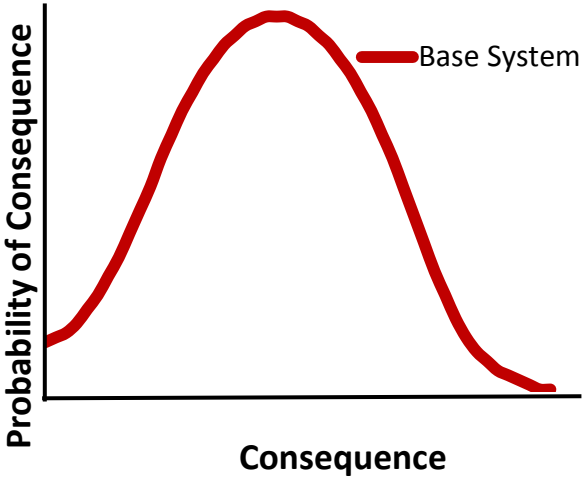
Consequence, Hurricane



Alternative units:
Safety
Economics
Population affected
etc…

An exemplar consequence distribution is created to account for uncertainty (Threat intensity, Available resources, System response, Interdependencies, Disruption impacts, etc.)

Distribution of Consequence, Hurricanes



This distribution is the RESILIENCE METRIC.

Electric Resilience Assessment Program for Distribution (ERAP-D)

Assessment tool for resilience of distribution utilities to extreme weather events, building on ANL's Infrastructure Survey Tool (IST)

Preparedness
- Awareness
- Planning

Mitigation Measures
- Mitigating Construction
- Alternate Site
- Resources Mitigation Measures

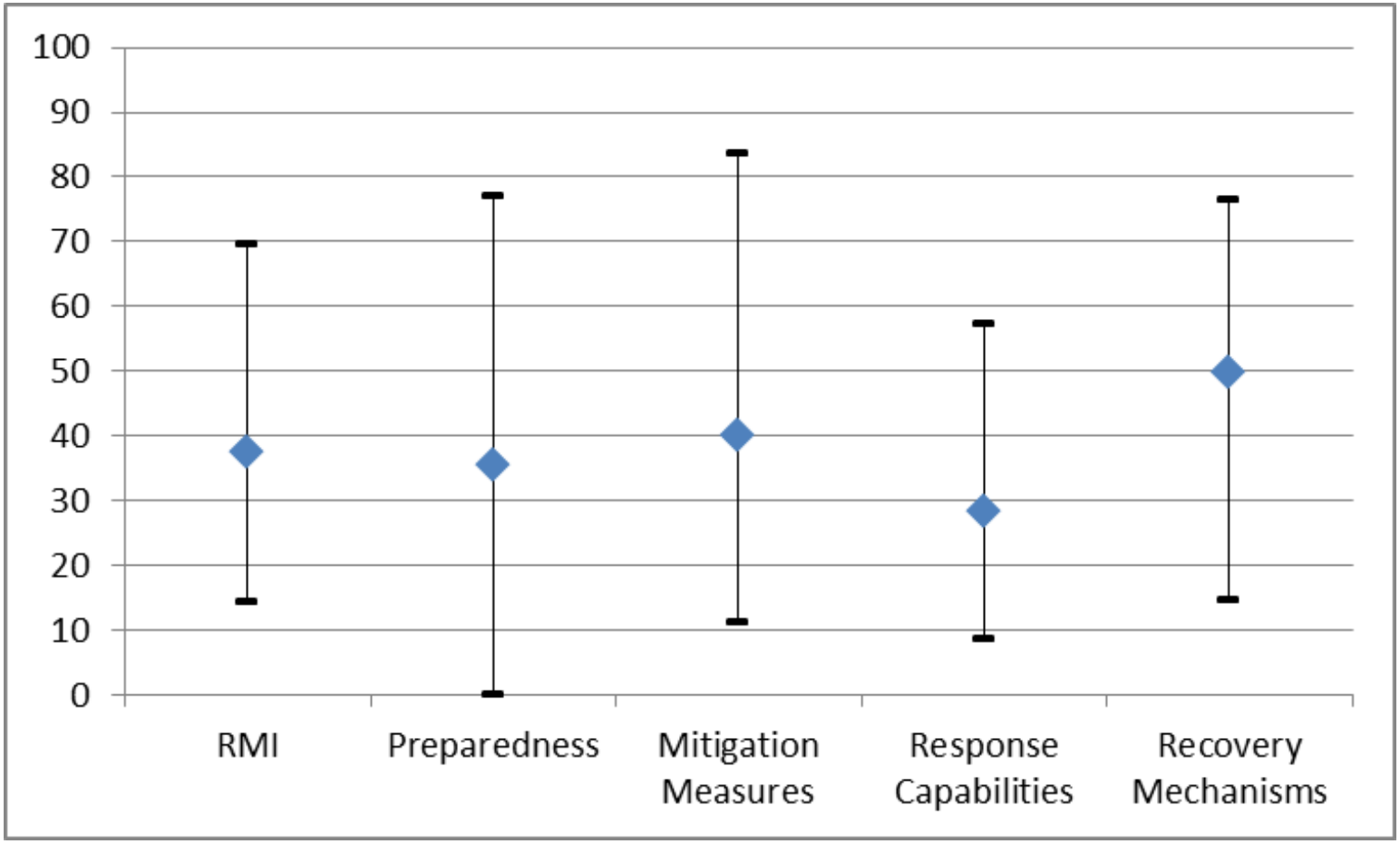
Response Capabilities
- Onsite Capabilities
- Offsite Capabilities
- Incident Management and Command Center Characteristics

Recovery Mechanisms
- Restoration Agreements
- Recovery Time

$$\mathrm{RMI} = \sum_{i=1}^{4} w_i \times D_i$$

RMI = Resilience Measurement Index (ranging from 0 [relatively low resilience] to 100 [relatively high resilience]);
W_i = Scaling constant (weight) indicating the relative importance of component *i* for the Resilience Measurement Index; and
D_i = Observation for component *i* for the Resilience Measurement Index (e.g., preparedness).

Example Display of Overall RMI and Component Indices



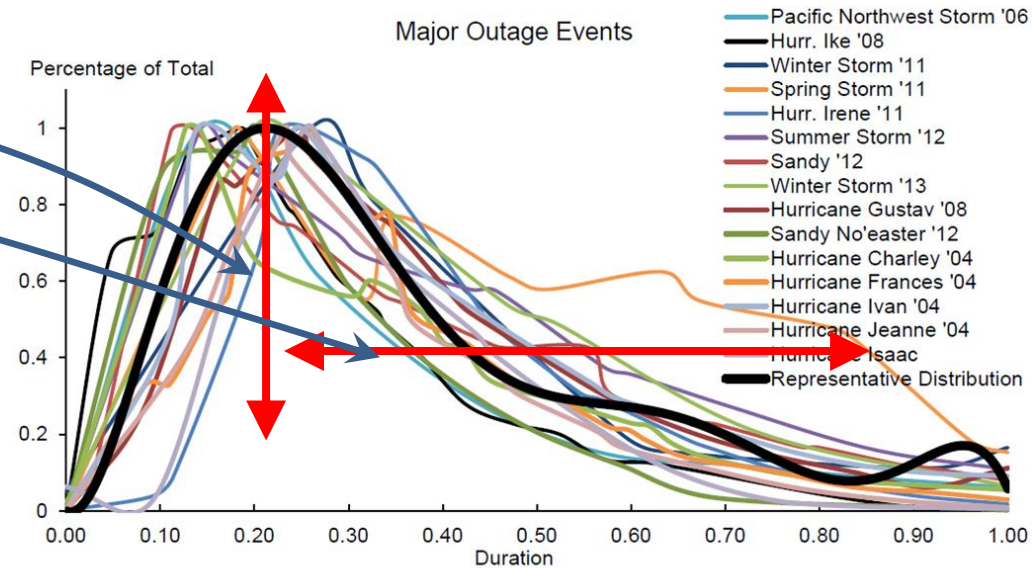
Decision Support Analysis Tool

Enable distribution grid designers to prioritize cost-effective system upgrades and expansions to minimize future damage to their grid and outages to customers

- **Hardening/Resilience options**
  - *Asset hardening*
  - *System design*
  - *System operations*
  - *Repair scheduling*
  - *Emergency operations*

withstand

recover



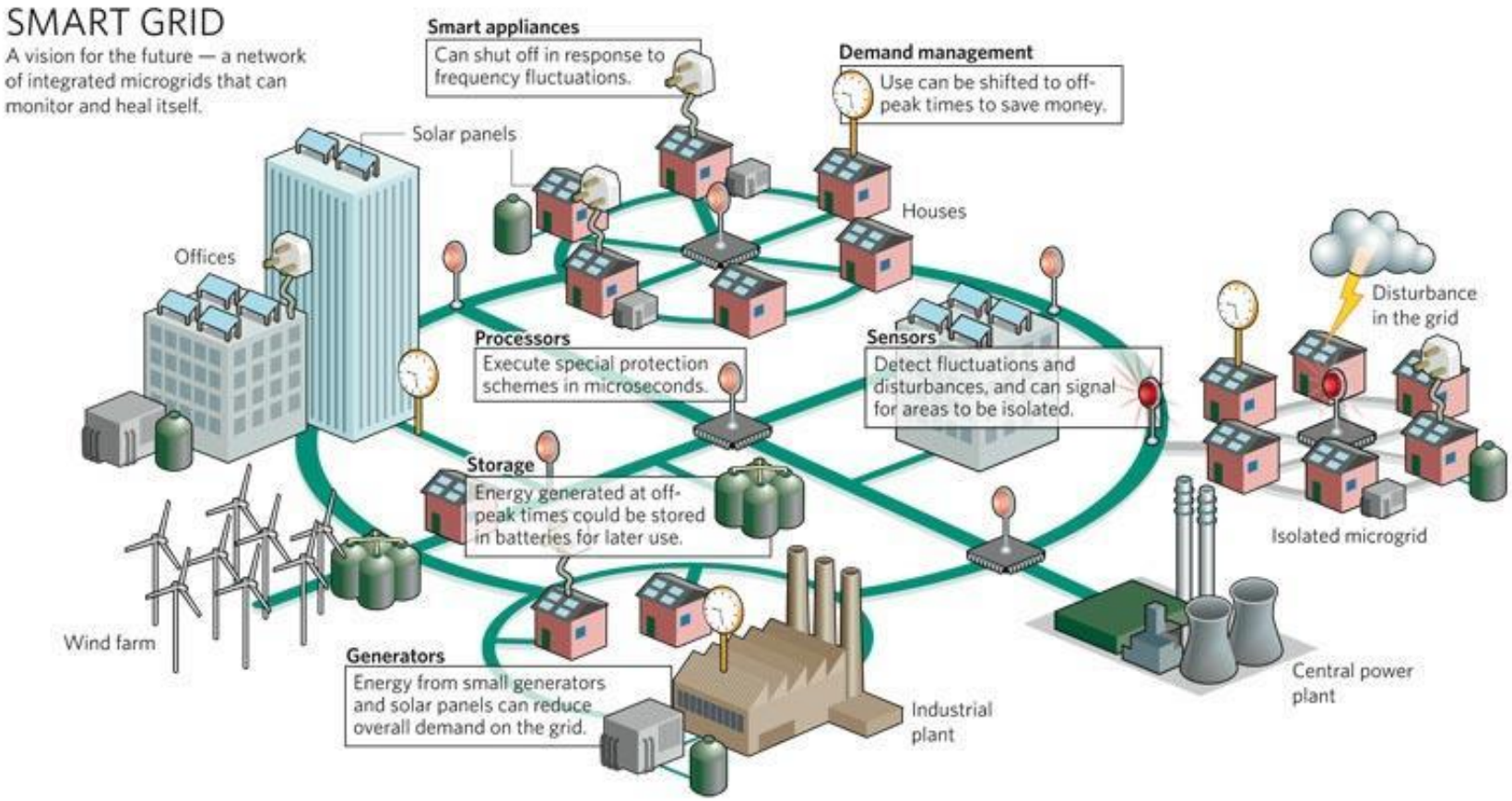
Source: Department of Energy, Office of Electrcity Delivery and Energy Reliability

- **Flexibility for the user**
  - *User's base network model*
  - *User-defined resilience metrics*
  - *User suggested upgrades*
  - *User-defined costs*
  - *User-defined threat and scenarios*

- **Tool capabilities**
  - *Assess current resilience posture*
  - *Optimize over user-suggested upgrades to improve resilience considering budget*

Leverage many existing modules developed under the DHS National Infrastructure Simulation and Analysis Center (NISAC)

Looking Forward:
Developing a Smarter, More Resilient Grid by Employing ADMS and Transactive Controls and Integrating Network of Microgrids



Picture courtesy of: Smart Grid 2030

Program Resources

Office of Electricity Delivery and Energy Reliability
http://www.oe.energy.gov

Smart Grid
http://energy.gov/oe/services/technology-development/smart-grid

Microgrids
http://energy.gov/oe/role-microgrids-helping-advance-nation-s-energy-system

Recovery Act Smart Grid Investments
https://smartgrid.gov

Questions?