Summary of Proposed Metrics – QER Technical Workshop on Energy Sector Resilience Metrics (4/29/2014)

Theory

- RAND presentation → Guidelines for measuring resilience
  - Resilience describes the state of service from a system in response to a disruption (e.g., % service provided/time)
  - Best metrics depend on who is measuring resilience and why (systems, disruptions, responses, timescales)
  - Resilience metrics are used for many purposes and at may levels (supporting both strategic and operational decision making)

Inputs	**Capacities**	**Capabilities**	**Performance**	**Outcomes**
What is available?	*How are inputs organized?*	*What tasks can be performed?*	*What is produced?*	*What is achieved?*
Examples: • Budgets • Equipment • Number of spare parts • Number of generators • Number of line workers	Examples: • Response teams • Plans • Aid agreements • Smart-grid tech	Examples: • Outage detection • Line repair • Backup delivery • Outage restoration	Examples: • Energy delivery • Efficiency • Reliability • Hardness • Robustness • Sustainability	Examples: • Economic activity • Costs and damage • Human welfare

  - No single set of metrics for all purposes
  - Selecting metrics requires balancing validity, reliability, and practicality in as few metrics as possible

- ANL Infrastructure Assurance Center presentation →
  - DEFINITION - Resilience, in the context of critical infrastructure, is defined as the ability of a facility or asset to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance
  - Relationship between Components of Resilience and Resilience-Enhancing Measures

Anticipate	Resist	Absorb	Respond	Adapt	Recover
Preparedness	**Mitigation**		**Response**		**Recovery**
Activities taken by an entity to define the hazard environment to which it is subject	Activities taken prior to an event to reduce the severity or consequences of a hazard		Immediate and ongoing activities, tasks, programs, and systems that have been undertaken or developed to manage the adverse effects of an event.		Activities and programs designed to effectively and efficiently return conditions to a level that is acceptable to the entity.

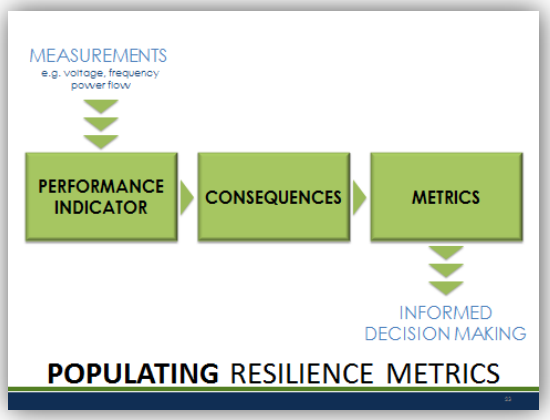
  - Developed data collection tool, dashboards and analysis results at the asset and regional levels to measure resilience of the Nation's critical infrastructure assets (16 sectors, energy is 1)

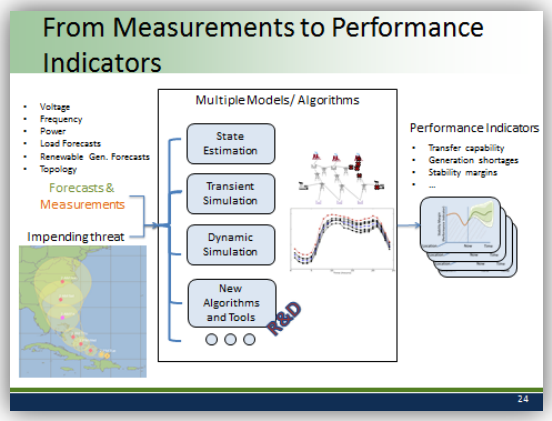
Sandia National Lab

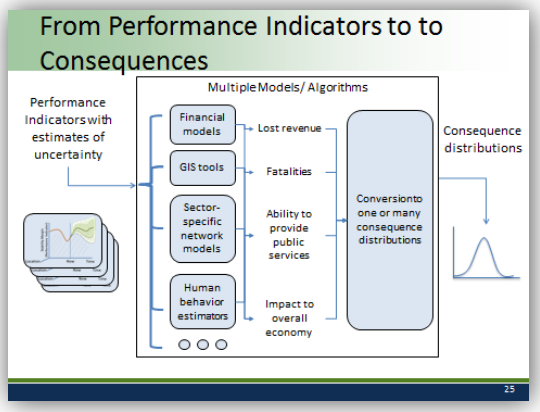
- General Framework for Developing Energy Resilience Metrics
  - What resilience metrics have to do:

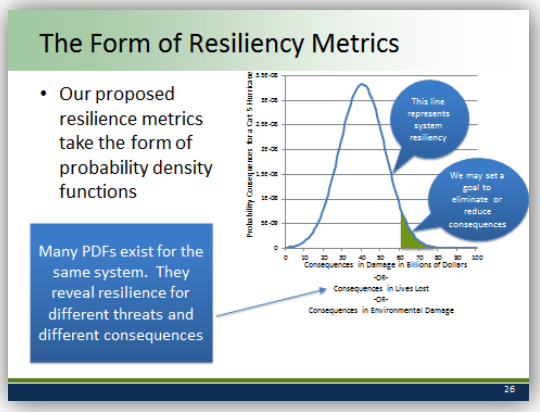
- Inform decision making
- Provide validity (they properly discriminate)
- Are repeatable (implementable)
- Be useable in a planning or operating context
- Allow for uncertainty quantification
- Be usable in an analytic context (such as an optimization algorithm)
- The resiliency framework must be scalable

- Metrics needed to enable resilience goals and decisions for U.S. national strategy
- A more resilient system exhibits improved performance (performance indicators = load served, recovery effort man power - labor, number damaged assets) and translates performance indicators into consequences (safety, economics, population effected), taking into account uncertainty (disruption impacts, system response, interdependencies with other systems, resources available) to enable decisions









- Prototype metrics – Use Cases created for electric power, oil, and natural gas systems
  - Applies common principles across energy sectors
  - R&D will be needed for advanced decision making

Electricity

- Con Ed presentation →
  - Storm Hardening and Resiliency Guiding Principles

Protect Infrastructure	Relocate and envelope equipment to minimize exposure to wind and water infiltration
Harden Components	Harden components – strengthen equipment to withstand water inundation and tree damage
Mitigate Impact	Improve flexibility to allow for advanced flow controls around damaged equipment
Facilitate Restoration	To identify location and description of damaged equipment, install remote monitoring and improve communications to expedite information flow

  - Metrics
    - Risk Assessment Methods
      - Vulnerability (estimates the vul of individual system assets based on the impact of electric system damage to customers and supporting critical infra)
      - Duration (the duration of an electric service outage, the likelihood of those assets being affected by either flooding or wind damage)
      - Hardening (the reduction of vul of those assets b/c of storm hardening initiatives)
    - Factors
      - Population (both indigenous and commuting population)
      - Critical infra (public and private facilities needed to support the health and safety of communities)
      - Outage duration (perhaps the single most exacerbating factor when electrical power is interrupted)
  - Model's goals
    - To gauge in terms of risk reduction to customers and critical infrastructure
    - Model quantifies and ranks the reduction in risk associated with each of the storm hardening projects related to the Company's transmission, substation, underground network, and overhead distribution systems.
    - Demonstrate a cost causality linkage between capital funding allocated for storm hardening and the reduction in risk obtained via that investment.
    - Rank all of the asset level risk reductions in highest to lowest order results in an indication of the relative risk reduction benefits across all resiliency programs.
- Dominion presentation →
  - Considerations – prior to, during, and after an event
  - Incident focused, post-incident learning
  - Modeling objectives
    - Systematic procedure (can apply at multiple locations)
    - Prioritize implementation
    - Identity N-k1-k2: inter-agency coordination
    - Understand the potential impact to the system
  - Static index
    - Load flow limit violations: voltage and line/transformer loading
  - Dynamic index
    - ISGA: response of state variable of generators
    - a: response of system topology
  - Severity ranking

- Resilience is a holistic concept (non-trivial metric)
  - Event physical/cyber, natural event, market, technologies
- Resilience requirements of an organization are a function of
  - System characteristics
  - Critical loads
  - Operating environment

Oil

- No hard metrics discussed; provided overview of oil production, distribution, transportation infrastructure

Natural Gas

- Kinder Morgan presentation → Pipeline resiliency considerations
  - Climate/Weather, Cyber, Physical impacts, equipment reliability, interdependence, supply sources, business resumption plans, inspection and measurements, staffing, delivery metrics

- AGA presentation → Potential metrics
  - Customer outages per customers served
  - Duration of customer outages per customers served
  - Security metrics → The Oil and Natural Gas Sector Coordinating Council, to which DOE is the Sector Specific Agency, has collected metrics for physical and cyber security. May also want to consider how quickly actionable info is shared by government