MAKING RESILIENCE A REALITY

DOE Electricity Advisory Committee (EAC)
July 9, 2018

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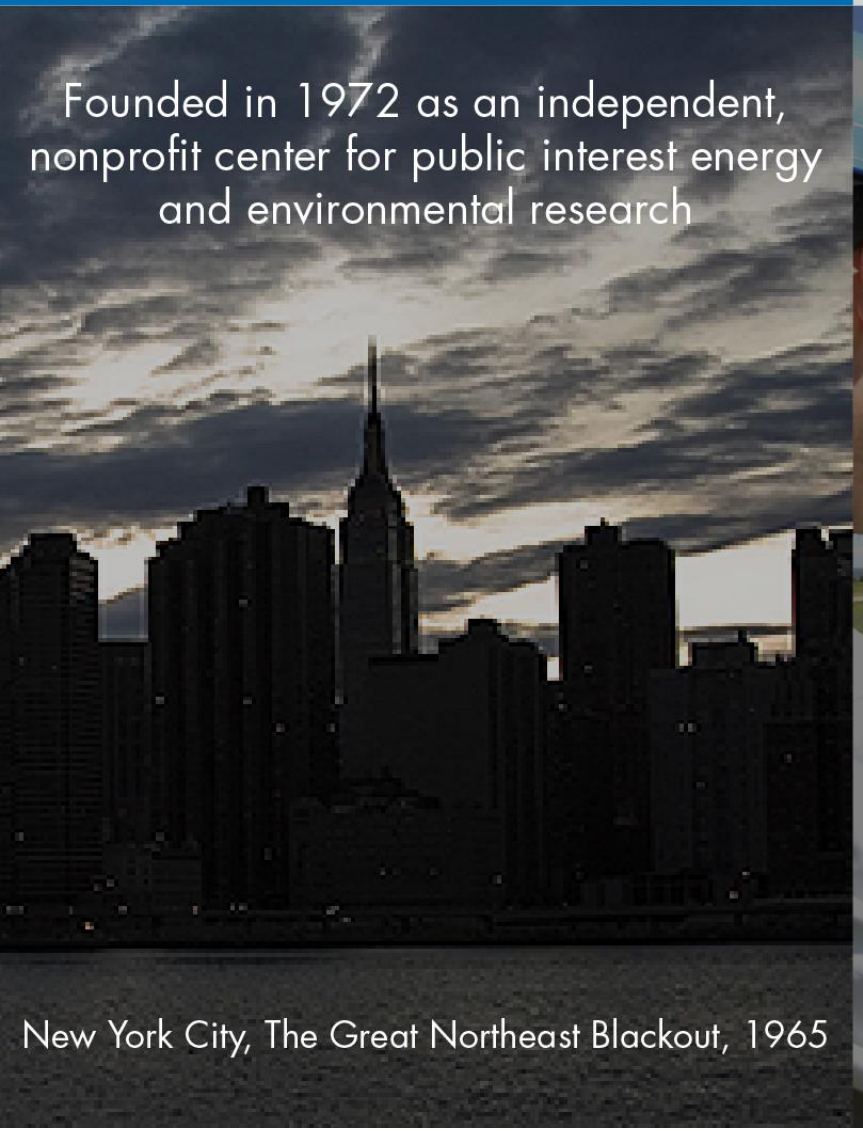
Electric Power Research Institute (EPRI)

Senior Vice President
External Relations and Technical Resources

Introduction to EPRI

BORN IN A BLACKOUT

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research



New York City, The Great Northeast Blackout, 1965

EPRI'S VALUE

To provide value to the public, our members, and the electricity sector

THOUGHT LEADERSHIP

INDUSTRY EXPERTISE

COLLABORATIVE MODEL

OUR MEMBERS…

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding – nearly 25% of EPRI's research, development, and demonstrations
- $415M Annual Funding

The Objective of Increasing Resilience - “The Why”

Quality of Life:

- Heating/Cooling
- Refrigeration
- Cell phones
- Internet

Economic impacts:

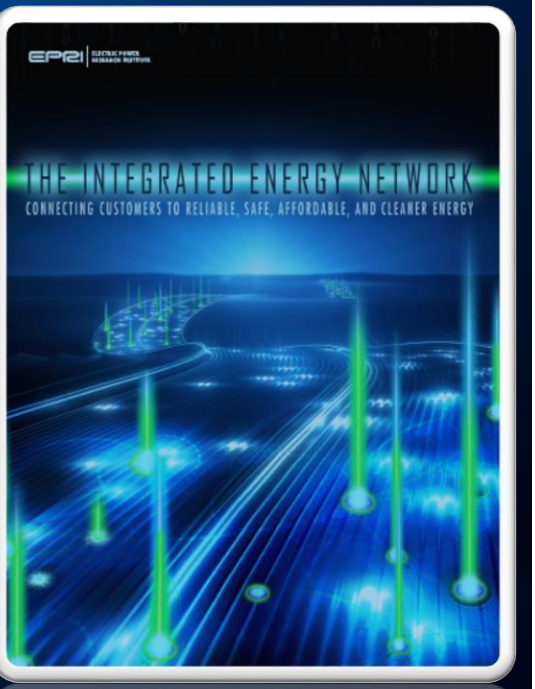
- Perished goods
- lost sales
- diminished worker hours and income

Diminished Emergency Services:

- Fire
- Law Enforcement
- Rescue Operations
- Medical Services/Medicine

Air Force photo by Capt. Christopher Merian in Puerto Rico

Integrated Energy Network

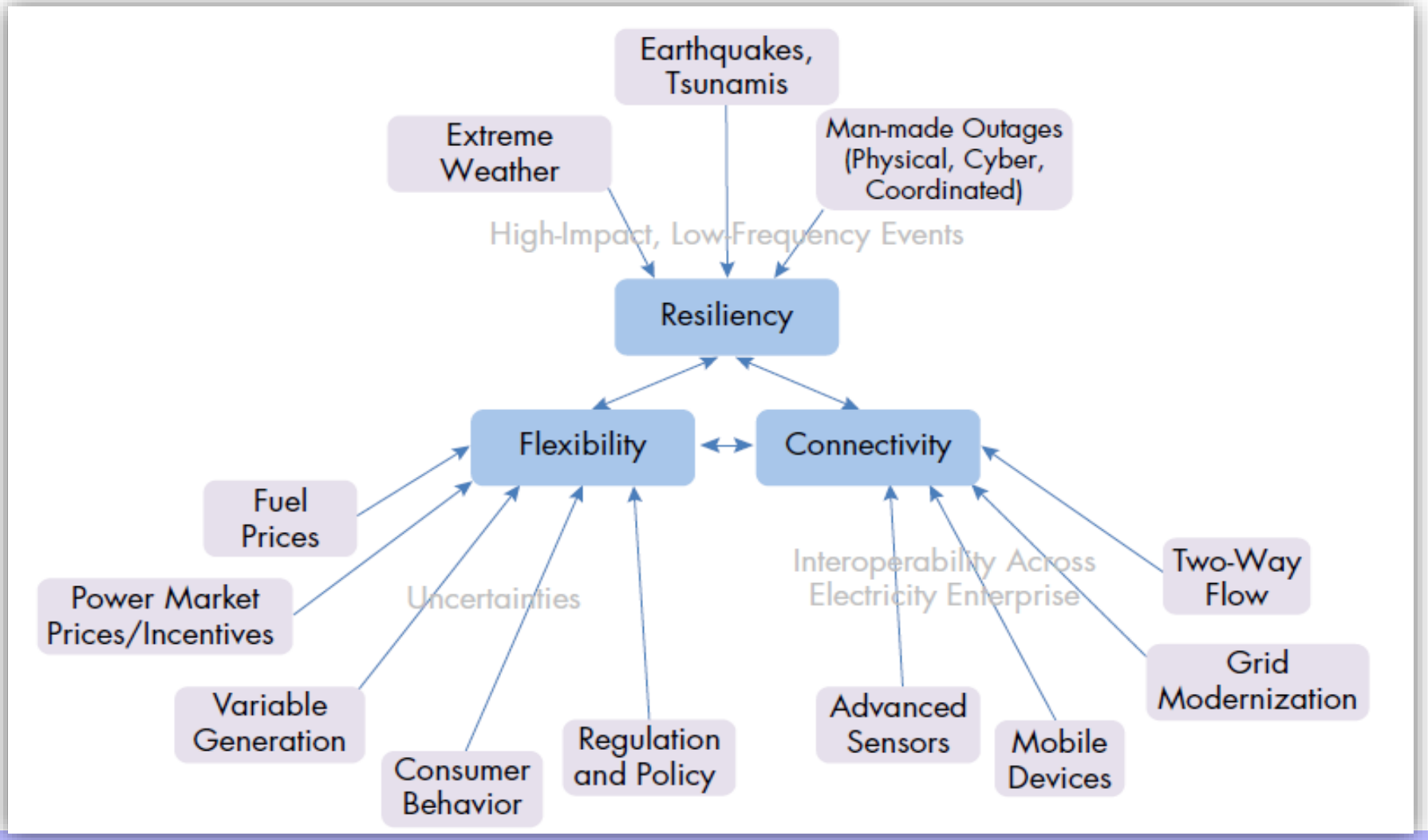


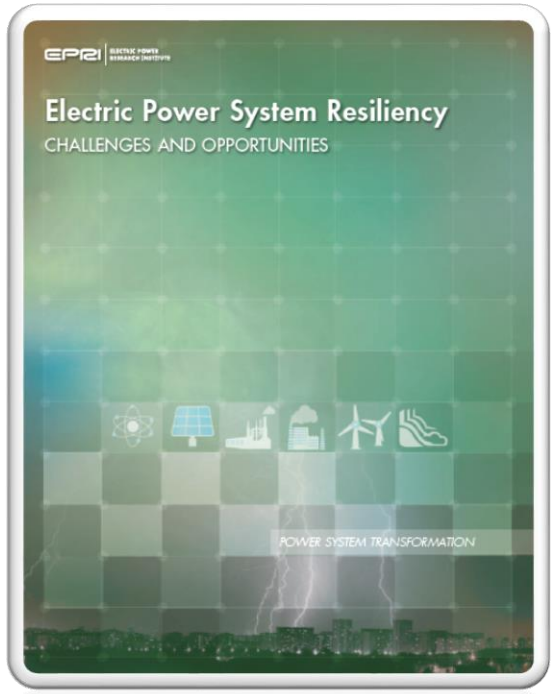
Source: EPRI 3002009917
February 2017

Integration of Interdependent Energy Resources:

Improves Reliability, Resiliency, Efficiency, Productivity, Create New Opportunities, and Expand Customer Choice

What is needed in an Integrated Energy Network?





Source: EPRI 3002007376 February 2016

Resiliency, Flexibility and Connectivity

Areas of Resilience Development – Identifying the "Parts"

- Framework and Models
- Interdependencies
- Threat Assessments
- Vulnerabilities (n-K)
- Impacts
- Mitigation Options
- Maturity Models
- Valuation
- Who Implements
- Who Pays

North America - U.S.

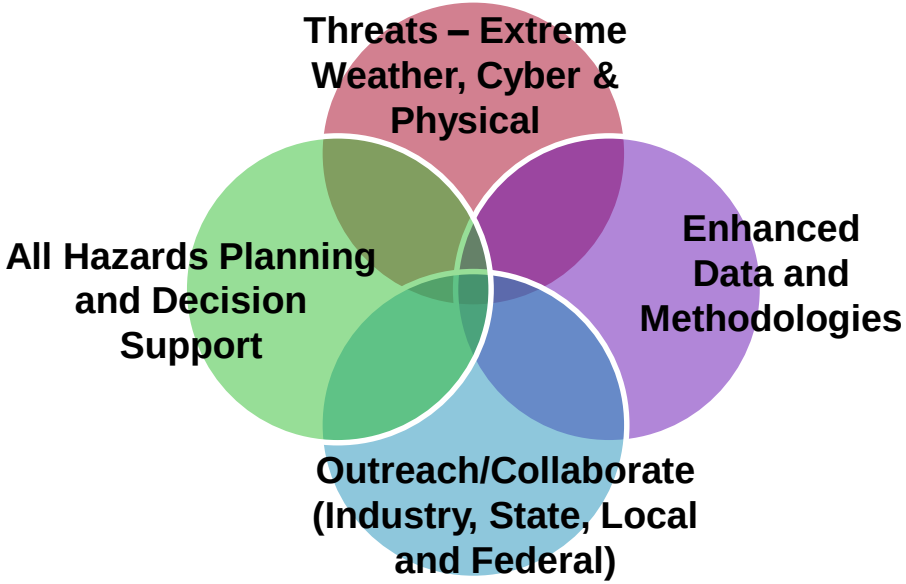
- 200,000 miles of Transmission Line > 230kV
- 58,000 substations between bulk transmission System and distribution feeder systems

Resilience Frameworks and Models – What Scope?

All Interdependent Energy Assets?

Source: EPRI 3002009917 February 2017

Key Gaps?



Source: DOE (C Zamuda) June 14, 2018

All Components of the Power System?

Source: EPRI 3002007376 February 2016

Modeling the Changing Power System

Variable Renewables & 2-way Power Flow

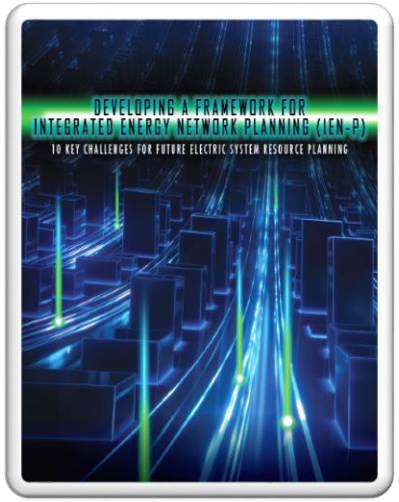
Bulk & Distributed Energy Storage

Increasing Reliance on Natural Gas

Customer Control & Choice

Demand Response

Efficient Electrification



Source: EPRI 3002010821
July 2018 (Pending)

"Existing processes need to change to incentivize or prioritize resource attributes that result in a system that not only is reliable in the face of typical electrical system contingencies, but also resilient to HILF, all-hazard events."

Electric System Resilience Needs to Identify Various Threats

Manmade/ Adversarial Hazards

EMP – High Altitude Electromagnetic Pulse

IEMI – Intentional Electromagnetic Interference

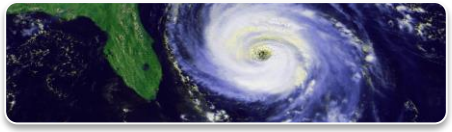
Cyber Terrorism

Coordinated Physical Assault

Natural Hazards

Seismic Event – High Magnitude Earthquake

GMD Geomagnetic Disturbance (Severe Space Weather)



Hurricanes, Ice Storms and Other Severe Weather Events (including Wildfires)

Hardening/ Prevention

Response/ Recovery

Customer/ Community/ Adaptability

Source: EPRI “Industry Insights on Transmission Resiliency” 3002009033 2016 Update July 2016

Identifying the Spectrum of Vulnerabilities

Examples: Both "Operating Technologies" (OT) and "Information technology" (IT)

Threats and Specific Vulnerabilities											
Severe Weather				Physical Attack		Electromagnetic			Cyber Attack		Workforce
Wind	Winter Storms	Earthquake	Floods/ Tsunamis	Substation Intrusion	Off-Site Attacks	EMP	IEMI	GMD	Corporate	ICS/SCADA	Epidemic Outbreak

Foundations & Poles

Fuel Availability

Equipment Misalignment

Submerged & Wet Equipment

Malfunction

Equipment Damage

Transmission & Control Equip.

Transmission & Control Equip.

Device Failures

Access to Sensitive Information

System Controls

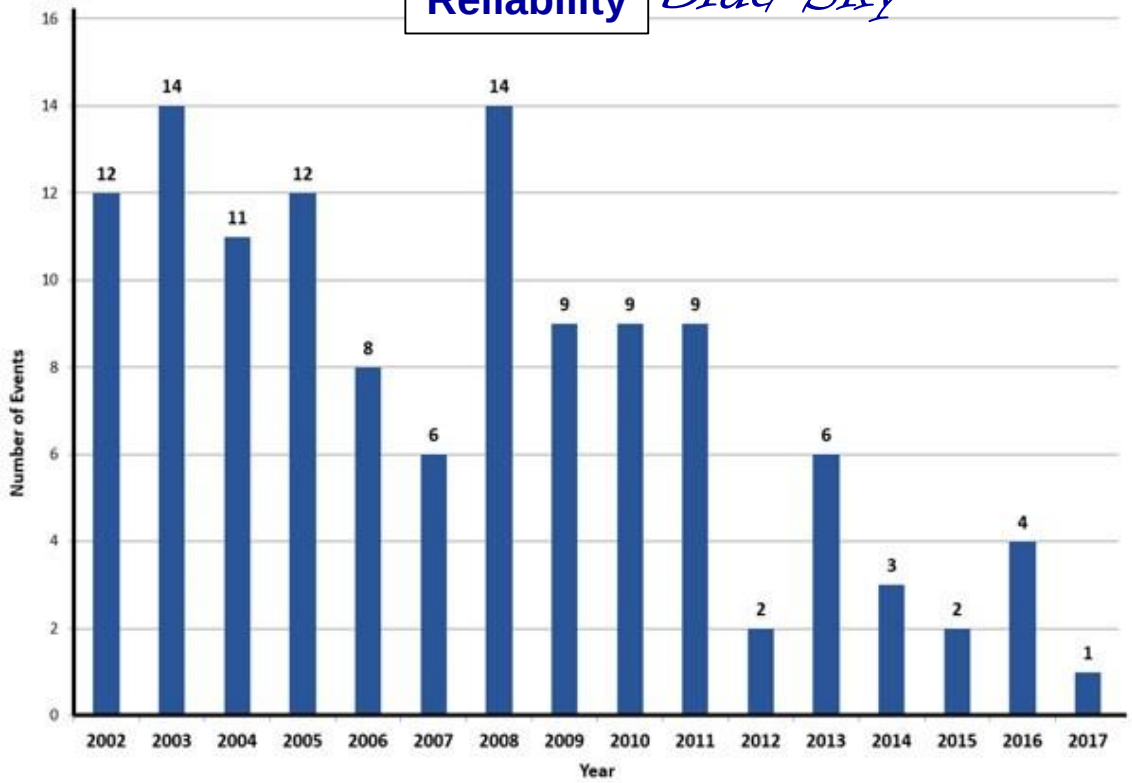
Limited Workforce

For High Impact, Low Frequency (HILF) Events: Identify the Specific "All Hazards" Vulnerabilities – All or Transmission System, Only?

Source: EPRI "Industry Insights on Transmission Resiliency" 3002009033 2016 Update July 2016

Impacts: Reliability versus Resiliency

Reliability *Blue Sky*



Bulk power system transmission events resulting in loss of load. Load loss was lower in 2017 than in any year since 2002.

Source: *RTOInsider, NERC, June 25, 2018*

Resiliency *Black Sky*

Hurricane Harvey, Texas (August 2017)

Utility

Customer

Regulator

Public

IMPACTS

Transmission Resilience – Mitigation Measures

Examples:

Modes of Mitigation	
Assess	• In-house assessment
	• Outside investigations
	• Establish informal SME network
Prevent/Harden	• Install physical barriers
	• Replace/Reinforce vulnerable components
	• Update security procedures
	• Develop operational guidelines
Detect/Monitor	• Establish weather related communications
	• Install seismic sensors
	• Install video monitoring equipment
	• Implement network logging and monitoring
Recover/Restore	• Join “Mutual Assistance” (EEI) and “Spare Equipment Database” (NERC)
	• Develop contingency plans/Training/Drills
	• Backup Generation
Adapt/Community	• Establish Communication Protocols (Emergency, Gov’t, Public, etc.)
	• Prioritized Restoration Plan
	• Implement “Shared Integrated Grid Plans”

Source: Partially from EPRI 3002007376 February 2016

Damage Prevention and Assessments Help Harden the System

(Examples of EPRI Transmission-related Work)

Anti-icing conductor work

Distribution Pole Attachments

Advanced Vegetative Management

Technical Support for GMD Standard

EMP Studies to inform utility investments

Climate Change Vulnerabilities and Adaptation for Electric System

Hardening/ Prevention

Response/ Recovery

Customer/ Community/ Adaptability

Response and Recovery Support Rapid Assessment and Repair

(Examples of EPRI Transmission-related Work)

Unmanned Aerial Systems

Black Sky Communications

Transmission Equipment Assessment Using Artificial Intelligence

EMS Contingencies

Specialized Equipment

Hardening/ Prevention

Response/ Recovery

Customer/ Community/ Adaptability

Response and Recovery Support Rapid Assessment and Repair

Communication, CIS, Integrated Grid Platform*

Microgrids

PV Systems as Backup

Storage for Grid Resilience

Restoration and Back up for Essential Services

Hardening/ Prevention

Response/ Recovery

Customer/ Community/ Adaptability

*Source: EPRI: "Evolving from CIS to an Integrated Grid Commerce Platform", 3002011966 (December 2017)

Multiple "Maturity Models" Support Resilience of the Grid

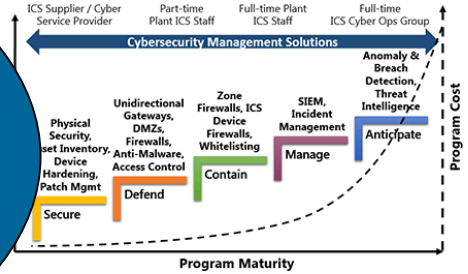
Resiliency Maturity Models

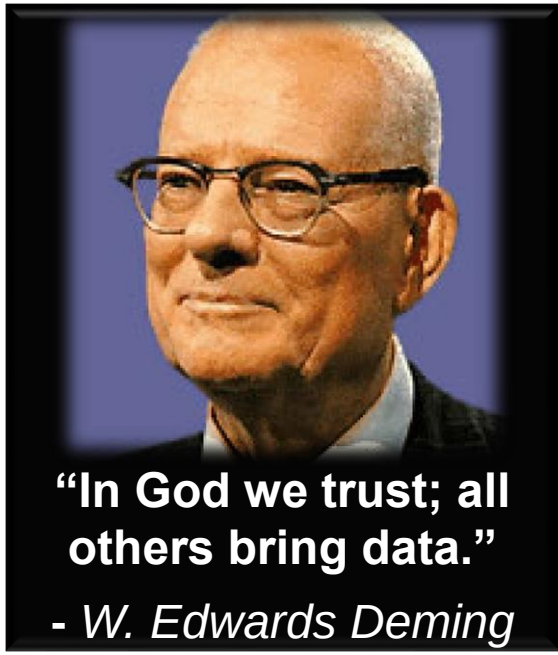
Source: EPRI (A. Phillips) June 14, 2018

January 2018 order, FERC proposed a definition for bulk power system resilience as:

"The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the ***capability to anticipate, absorb, adapt to, and/or rapidly recover*** *from such events."*

Cyber Maturity Models

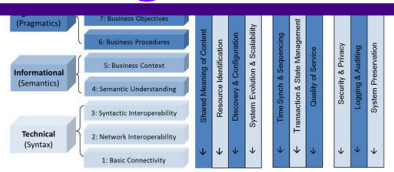




"In God we trust; all others bring data."

- W. Edwards Deming

Smart Grid Maturity Models



Source: Smart Grid Interoperability Maturity Model Summary, Gridwise Architecture website

Customer Resiliency Maturity Models

How is Resiliency Valued? Benefit - Cost

1. Probabilistic Risk Assessment
2. Adequacy of Value of Lost Load (VoLL)
3. Standard/Metrics Based Criteria
4. Multiple Value Streams Beyond Resiliency
5. Shared Integrated Grid Resources

Responsibility for Resilience - Crosses Many Lines

Federal

U.S. DEPARTMENT OF ENERGY

Homeland Security

FERC Federal Energy Regulatory Commission

NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Other Federal Government Entities

State

National Association of Regulatory Utility Commissioners

NASEO National Association of State Energy Officials

AMERICAN PUBLIC POWER ASSOCIATION

NGA NATIONAL GOVERNORS ASSOCIATION

NRECA America's Electric Cooperatives

RTOs/ISOs – Balancing the System

Other

EPRI ELECTRIC POWER RESEARCH INSTITUTE

EEI Edison Electric INSTITUTE

NEI NUCLEAR ENERGY INSTITUTE

GRIDWISE ALLIANCE

AGA American Gas Association

Academia

Advocacy Organizations

Energy Providers – IOUs, Munis, Coops

Who Should Pay for a Resilient Power System?*

Existing Utility Customers

All Taxpayers in a State

Who PAYS for WHAT?

Regional Electricity Customers

Federal Budgets

*Source: Public Utilities Fortnightly, “Who Should Pay for Resilient Power System?”, Elliott Roseman, (May 2018)

Key Areas of Resiliency Focus: DOE OE and EPRI

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Key Areas of Resiliency:

1. ***Integrated Energy Network Resiliency Modeling***
2. ***T&D Infrastructure Modeling/NATF***
3. ***Customer Resiliency***
4. ***Cyber and ICT Resiliency***

"Five Pillars"

U.S. DEPARTMENT OF ENERGY

Bruce Walker, Assistant Secretary, Office of Electricity

- Transmission Planning
- Data Analysis/AI
- T&D Cyber
- Energy Storage (MW)
- Puerto Rico (test bed)

Protection of National Security

17 National DOE Labs and Public, Private Partnerships

Electric Grid is 1 of 16 DHS National Critical Infrastructures

Together…Shaping the Future of Electricity