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U.S. Department of Energy

Toward All-Hazards Security and Resilience for the Power Grid

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National Renewable Energy Laboratory

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U.S. DEPARTMENT OF ENERGY

Grid Modernization Vision

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*The future grid provides a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It must deliver **reliable, affordable,** and **clean electricity** to consumers where they want it, when they want it, how they want it.*

Enhance the Security of the Nation

- Extreme weather
- Cyber threats
- Physical attacks
- Natural disasters
- Fuel and supply diversity
- Aging infrastructure

Sustain Economic Growth and Innovation

- New energy products and services
- Efficient markets
- Reduce barriers for new technologies
- Clean energy jobs

Achieve Public Policy Objectives

- 80% clean electricity by 2035
- State RPS and EEPS mandates
- Access to reliable, affordable electricity
- Climate adaptation and resilience

Key Future Grid Attributes

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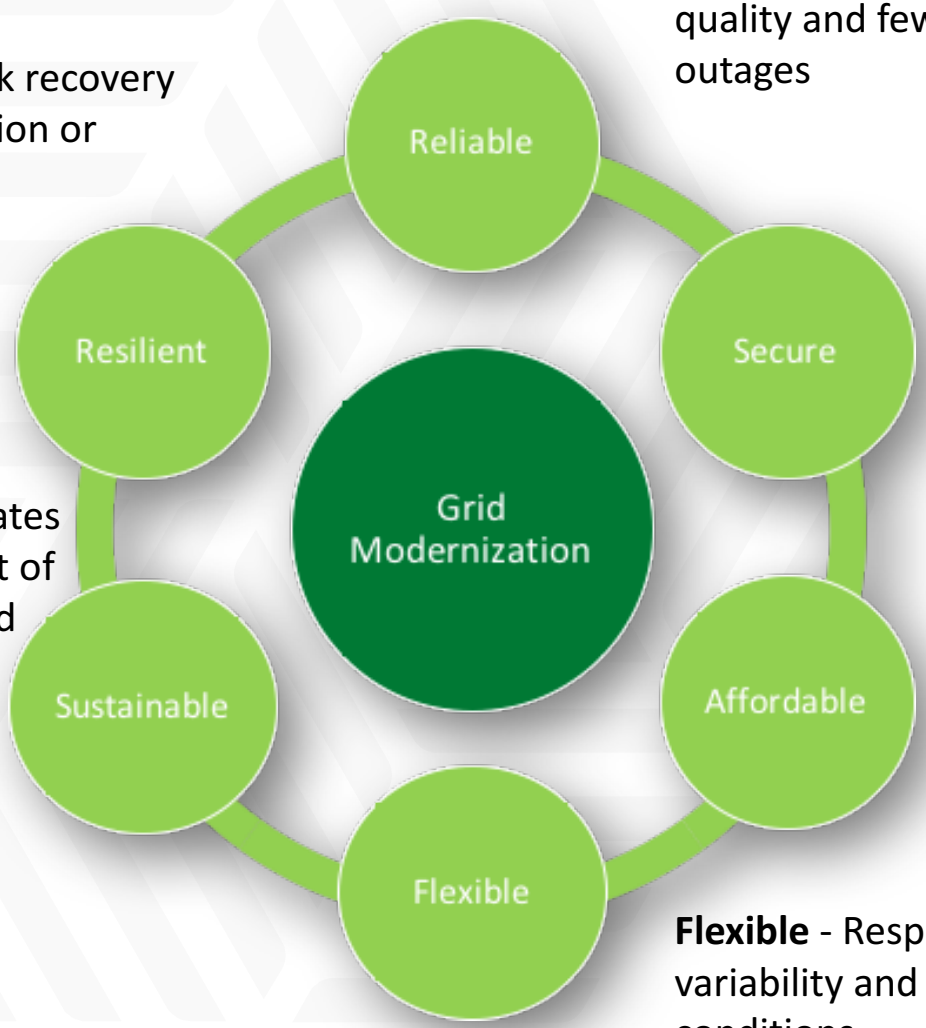
Reliable - Improves power quality and fewer power outages

Resilient - Quick recovery from any situation or power outage



Secure - Increases protection to our critical infrastructure

Sustainable - Facilitates broader deployment of clean generation and efficient end use technologies

Affordable - Maintains reasonable costs to consumers.

Flexible - Responds to the variability and uncertainty of conditions

The Grid Modernization Lab Consortium (GMLC)

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Pacific Northwest NATIONAL LABORATORY

Sandia National Laboratories

BROOKHAVEN NATIONAL LABORATORY

Los Alamos NATIONAL LABORATORY

Argonne NATIONAL LABORATORY

SRNL SAVANNAH RIVER NATIONAL LABORATORY

SLAC NATIONAL ACCELERATOR LABORATORY

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NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

BERKELEY LAB

INL Idaho National Laboratory

NETL

THE Ames Laboratory
Creating Materials & Energy Solutions
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Grid Modernization Multi-Year Program Plan (MYPP)

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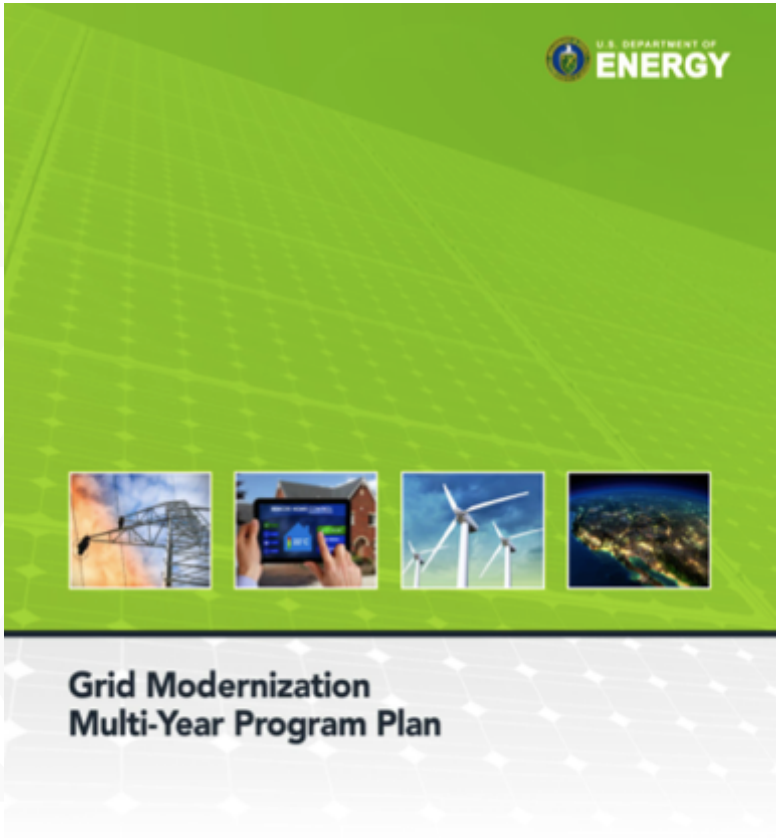
Foundational R&D

- Devices and Integrated Systems
- Sensing and Measurement
- System Operations and Control
- Design and Planning Tools
- Security and Resilience
- Institutional Support

Regional Demonstrations

- Low Reserve Margin Demo
- Clean Distribution Feeder
- Grid Analytics Platform



http://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp

Security and Resilience

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Expected Outcomes

- Holistic grid security and resilience, from devices to micro-grids to systems
- Inherent security designed into components and systems, not security as an afterthought
- Security and resilience addressed throughout system lifecycle and covering the spectrum of legacy and emerging technologies

Federal Role

- Lead and establish security and resilience research programs to develop technology solutions and best practice guidance
- Improve adoption of security and resiliency practices, and provide technology-neutral guidance
- Inform stakeholders of emerging threats and help address threats appropriate for government response

The Challenge:
Threats to the grid are increasing and continually evolving

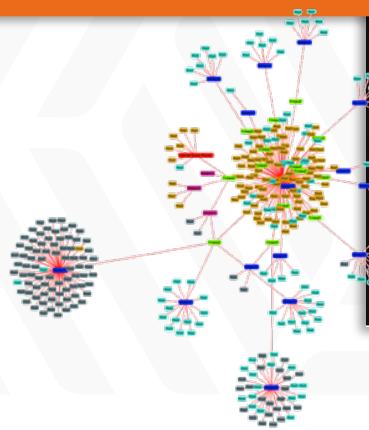


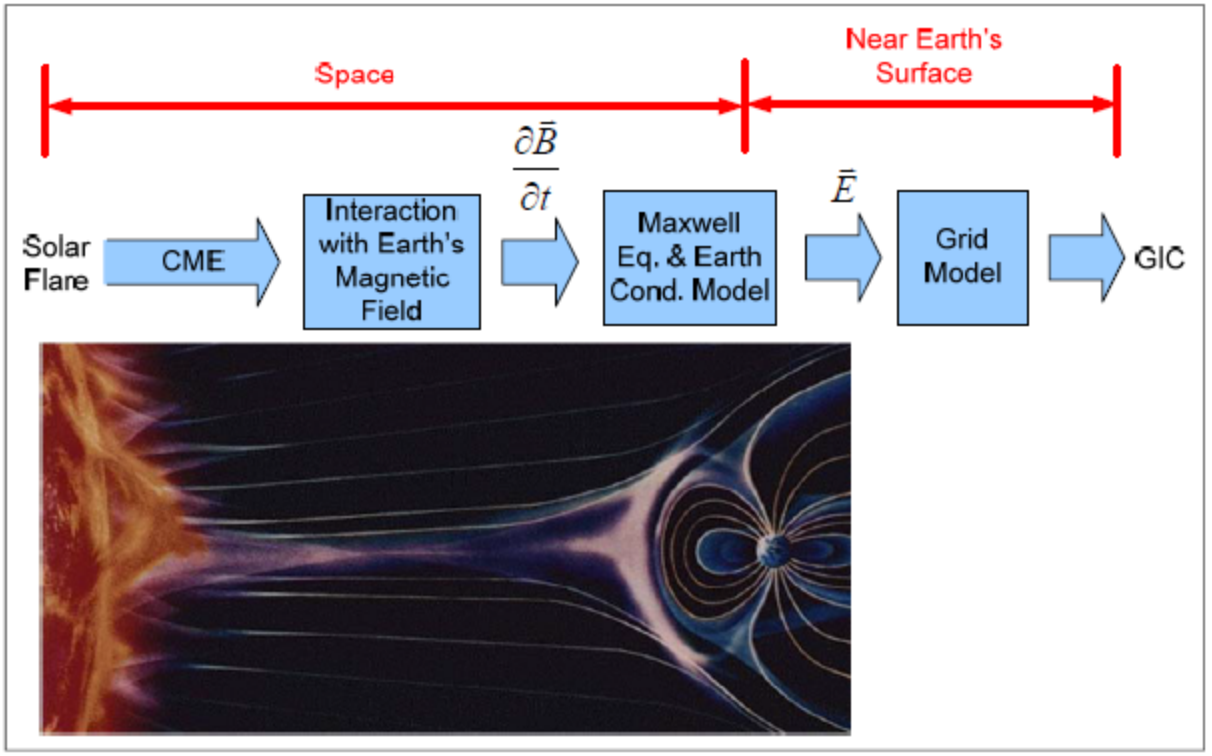
Table 1: Risk Landscape

Risk Area	Opportunities for Improvement
Naturally Occurring Hazards	
• Geological (e.g. earthquake)	Plans typically in place
• Meteorological	
○ Severe storm	Plans typically in place
○ Extreme water flows (drought, flood)	Plans typically in place
○ Extreme temperature	Plans typically in place
○ Geomagnetic disturbance (GMD), solar magnetic disturbance (SMD)	Requires additional action
• Biological disease (e.g. pandemic)	Plans typically in place
Human-Caused (Unintentional) Hazards	
• Hazardous material spill or release	Plans typically in place
• Explosion, fire	Plans typically in place
• Interdependency (e.g. fuel shortage, telecommunications service disruption)	Plans typically in place
• Human operational error	Plans typically in place
Human-caused (Intentional) Hazards:	
• Local criminal activity or sabotage	Plans typically in place
• Civil disturbance, riot	Plans typically in place
• Strike or labor dispute	Plans typically in place
• Terrorism	Requires additional action
• Physical attack	Requires additional action
• Electro-magnetic pulse (EMP)	Beyond the scope of the industry
• Cyber security breach, coordinated cyber attack	Requires additional action
Technological Hazards:	
• Equipment failure	Plans typically in place
• Local information/control system failure	Plans typically in place
• Local telecommunications system failure	Plans typically in place

Source:
Critical Infrastructure Strategic Roadmap,
NERC
Electricity Sub-Sector Coordinating Council
November 2010

Risks to the Grid from Geomagnetic Disturbance

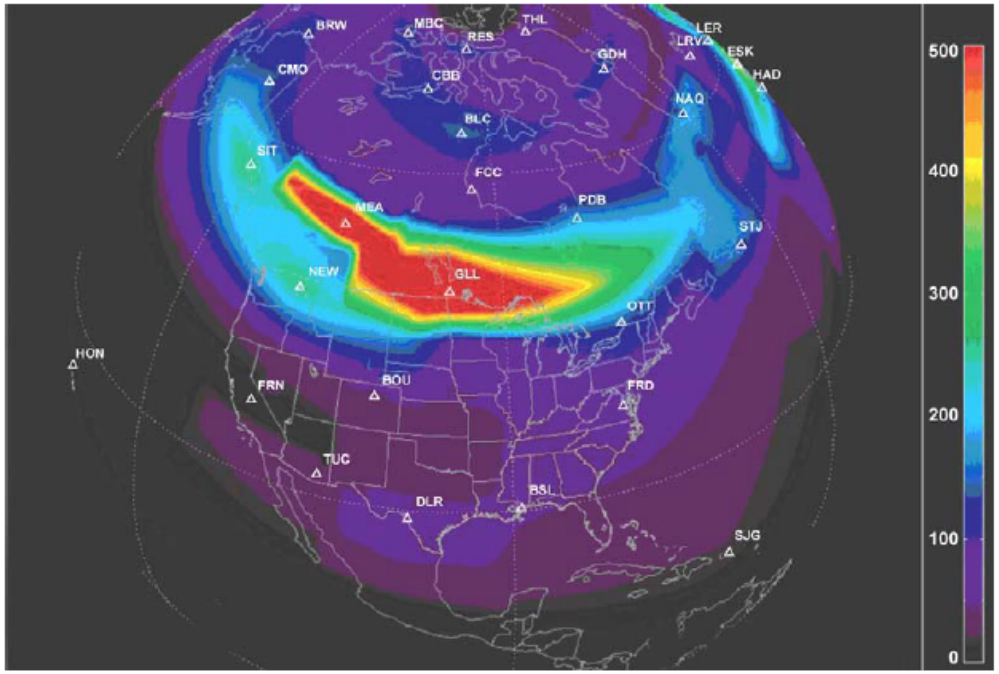
- Damage to bulk power system assets, typically associated with transformers
- Loss of reactive power support, which could lead to voltage instability and power system collapse.



Source: NERC 2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System

Solar Storm Example

- 1989 Hydro-Quebec outage due to solar storm
- 6M people affected
- 9 hour outage



Geomagnetic intensity–March 1989 storm

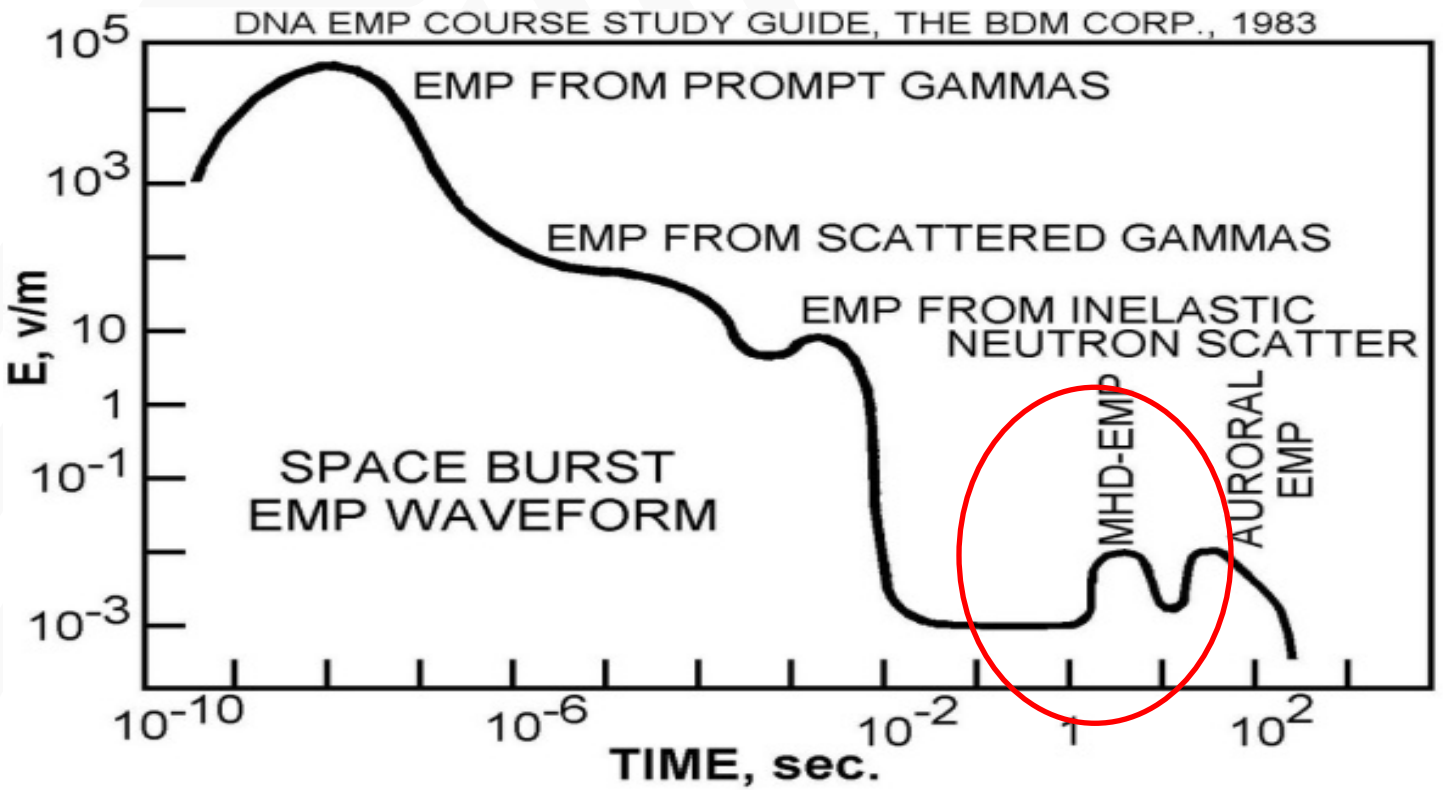
Source:
NERC 2012 Special Reliability Assessment Interim Report:
Effects of Geomagnetic Disturbances on the Bulk Power System

Electromagnetic Pulse (EMP)

- The term electromagnetic pulse is a burst of electromagnetic radiation that results from an explosion (especially a nuclear explosion). The resulting electric and magnetic fields may couple with electrical/electronic systems to produce damaging current and voltage surges.

- The effects of EMP on the electrical power system are fundamentally partitioned into its early, middle and late time effects
  - E1, (early) very fast component of nuclear EMP
  - E2, (middle) similar to electromagnetic pulses produced by lightning
  - **E3, (late time)** or Magnetohydrodynamic (MHD) very slow pulse lasting tens to hundreds of seconds (the E3 pulse is similar to the effects of a geomagnetic storm (Although, the MHD-E3 has similar frequency content to a geomagnetic storm, its intensity can be considerably higher.)

EMP Waveform as a Function of Time



Cyber and Physical Attacks on the Grid

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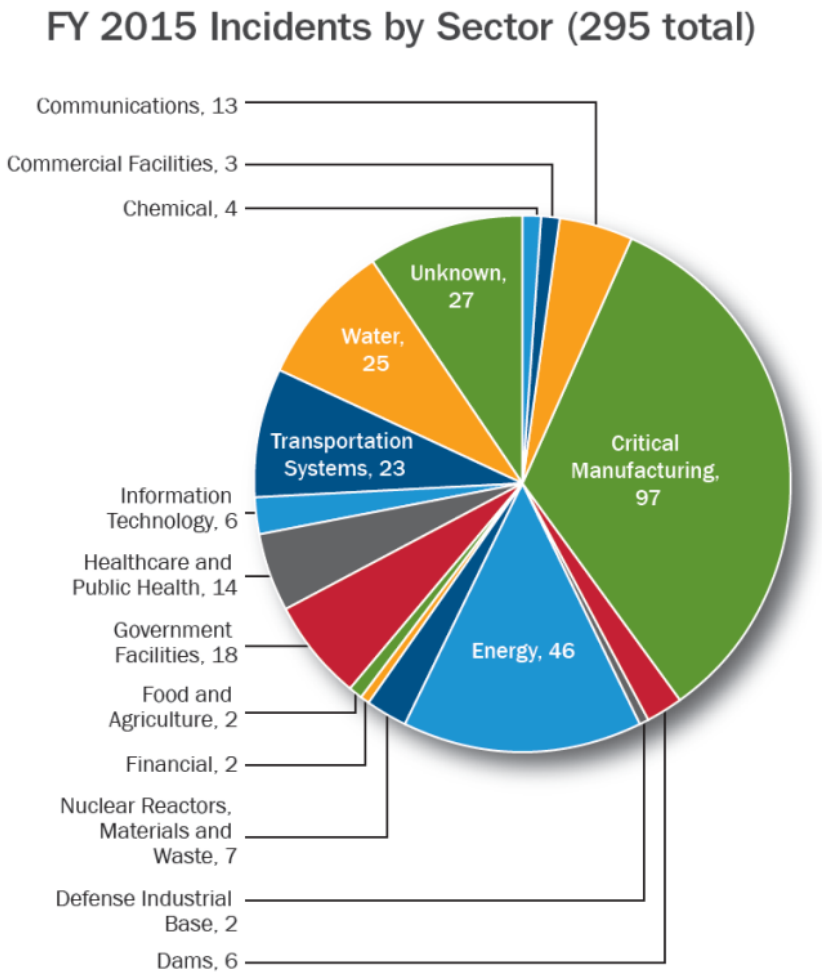
- April 16, 2013 - Metcalf substation near San Jose, CA sustained a combined physical and cyber attack
- December 23, 2015 - Cyber attack on Ukraine power distribution systems is first cyber attack resulting in power grid disruption

Indications of Cyber Adversary Interest

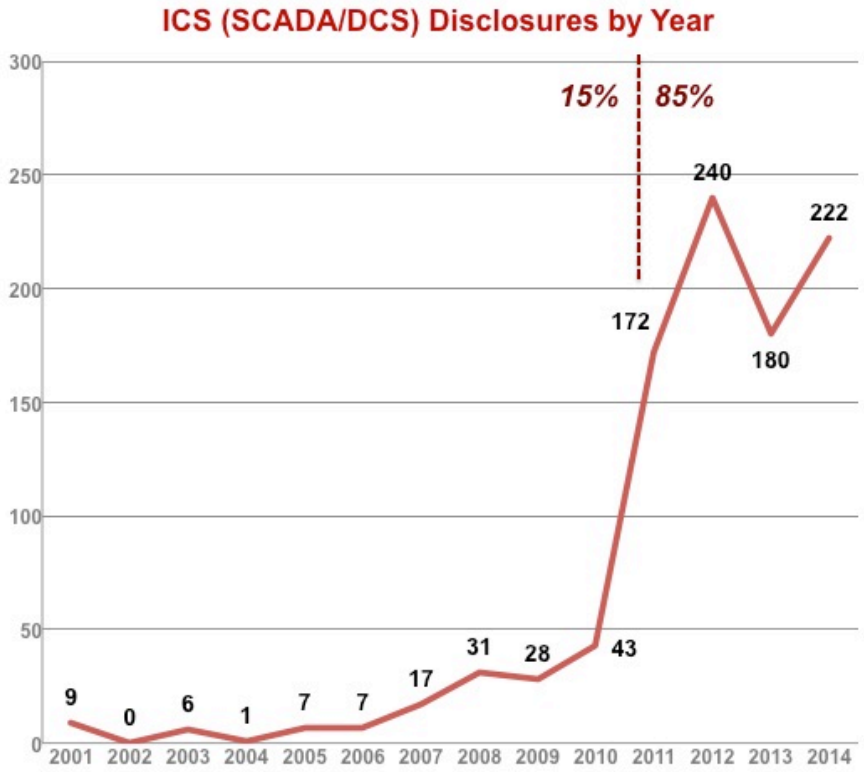
The 2015 Global State of Information Security Survey reported that power companies and utilities around the world expressed a **six-fold increase in the number of detected cyber incidents over the previous year.**



Source: NCCIC/ICS-CERT Year in Review

What is the Cost of Cybersecurity?

The Open Source Vulnerability Database (OSVDB) is an independent and open source database created by and for the security community.



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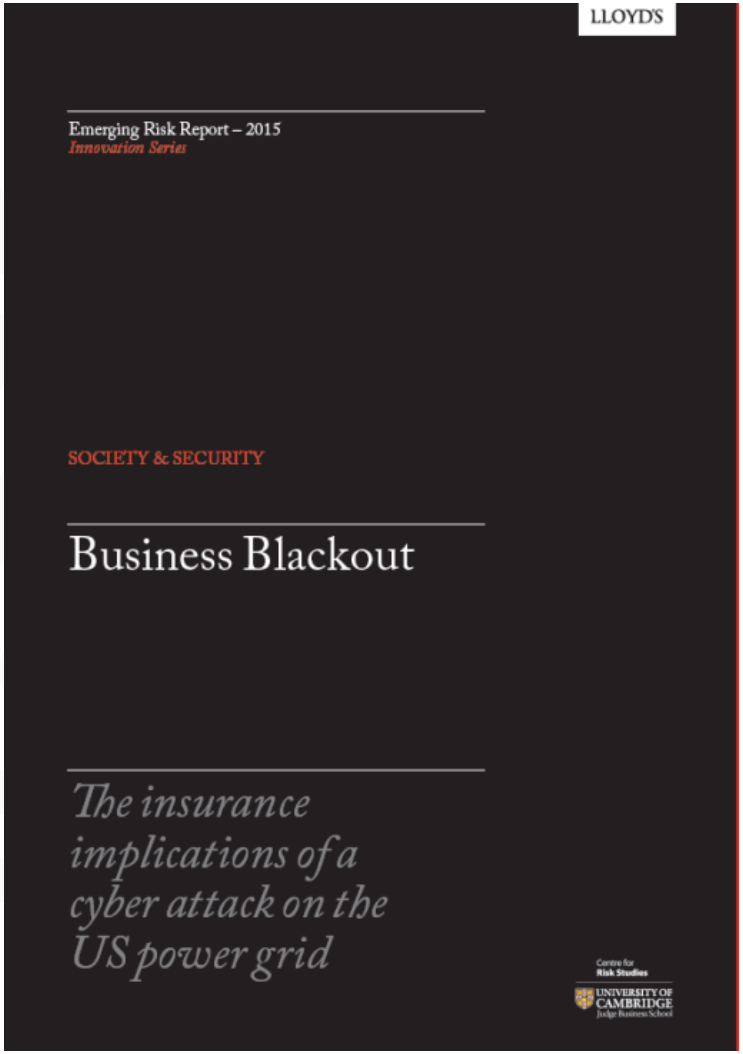

GMLC Framework for Security and Resilience

Based on NIST Cybersecurity Framework

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Identify:

Develop understanding of threats, vulnerabilities, and consequences to all hazards

Outcome: Improved risk management and streamlined information sharing

Protect:

Inherent system-of-systems grid resilience

Outcome: Increase the grid's ability to withstand malicious or natural events

Detect:

Real-time system characterization of events and system failures

Outcome: Accelerated state awareness and enhanced event detection

Respond:

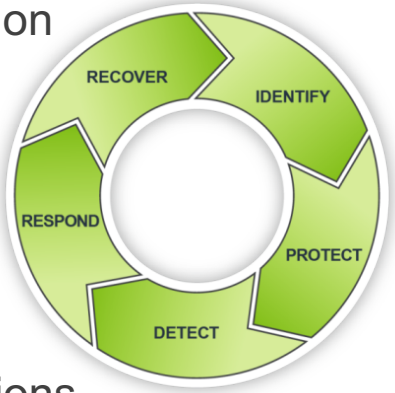
Maintain critical functionality during events and hazards

Outcome: Advanced system adaptability and graceful degradation

Recover:

Real-time device management and transformer mobilization

Outcome: Timely post-event recovery of grid and community operations



Thank you!